Department of Science and Agriculture,

BARBADOS.

AGRICULTURAL JOURNAL

Vol. 1 No. 1. **January 1932.**

ADVOCATE CO., LTD.,—Printers & Bookbinders to the Government of Barbados.

CONTENTS.

	PAGE.
An Investigation into the Evolution of Sugar Cane Varieties by breeding in Barbados, 1887–1925, with a Discussion on the Application of the Findings to the present day Scheme of Work by A. E. S. McIntosh, B.Sc., Ph.D.	3
A Survey of the position of *Phytalus smithi*, Arrow, and its Natural Enemies in Barbados by R. W. E. Tucker, M.A., B.Ed.	18
The Scientific Control of Pan Boiling by S. J. Saint, M.Sc., Ph.D., F.I.C.	24
The Status of *Trichogramma* as a Control of *D. saccharalis* in Barbados by R. W. E. Tucker, M.A., B.Ed.	29
The Inversion of Sucrose in Syrup Manufacture by C. A. Coppin, B.A.Sc., (Toronto)	37
Some Aspects of the Flora of Barbados by F. Hardy, B.A., F.G.S.	41
Memorandum on the Cotton Situation in Barbados	63

DEPARTMENT OF SCIENCE AND AGRICULTURE.

STAFF.

Director of Science and Agriculture	R. W. R. Miller, B.A., (Camb.), A.I.C., Dip. Agric. (Cantab).
Assistant Director	C. C. Skeete, B.A., (Cantab).
Geneticist	A. E. S. McIntosh, B.Sc., Ph.D., (Edin).
Agricultural Chemist	S. J. Saint, M.Sc., Ph.D., F.I.C.
Assistant to Professor of Chemistry ..	T. A. E. Barker, B.Sc., (London).
Lecturer in Natural and Agricultural Sciences	W. A. McD. Paterson, B.Sc.
Entomologist	R. W. E. Tucker, M.A. (Cantab), B.Ed. (Capetown).
Veterinary Officer	C. P. Stoute, M.D.V. (Acting).
Chief Analytical Assistant	C. A. Coppin, B.A.Sc. (Toronto).
Plant Diseases Inspector	D. R. D. Wiles, D.I.C.T.A.
Chief Clerk	H. O. Ramsey.
Second Clerk	G. D. Ramsey.
Third Clerk	C. G. Humphrey.
Fourth Clerk	B. G. Barrow.
First Field Assistant	C. B. Foster.
Second Field Assistant	H. E. Ward.
Third Field Assistant	C. C. Corbin.
Fourth Field Assistant	F. E. Bynoe.
Analytical Assistant	H. A. Jones.
„ „	C. St. A. Alleyne.
„ „	L. A. Hall.
Botanical Assistant	L. H. Atkinson
Foreman in Charge of Nurseries ..	S. A. Eastmond.

Department of Science and Agriculture,

Queen's Park,

Bridgetown.

February 1, 1932.

In future the Report of the Department of Science and Agriculture will be published in four quarterly instalments.

2. The April instalment will be a brief summary of the year's work—those published in July and October will present the results of experimentation, while the January number will be devoted as far as possible to original scientific papers.

R. W. R. MILLER,

Director of Agriculture.

Digitized by the Internet Archive
in 2025

https://archive.org/details/agricultural-journal_1932-01_1_1

AN INVESTIGATION INTO THE EVOLUTION OF SUGAR CANE VARIETIES BY BREEDING IN BARBADOS, 1887—1925, WITH A DISCUSSION ON THE APPLICATION OF THE FINDINGS TO THE PRESENT DAY SCHEME OF WORK.

By

A. E. S. McINTOSH, B.Sc., Ph.D.

INTRODUCTION.

This paper does not aim at the comprehensiveness of the detailed historical accounts of Bannier (1) and Posthumus (2) of the sugar cane breeding in Java from 1893-1928, as the nature of the records of the breeding work carried on in Barbados since 1887 precludes the possibility of such a detailed account. It is the object here, to present, as far as records will permit, a condensed account of the methods employed in breeding and seedling selection, with notes on the parent varieties employed, the successful seedlings resulting and to detail the more important genealogies.

It was considered that such an investigation might give information on successful "lines" of breeding in the past and suggest for the present work the selection of successful parent varieties with methods of their use most likely to give good results.

The published records consulted are listed (3) while the writer had also access to the unpublished sugar cane breeding and seedling selection records of the Department.

HISTORICAL.

It might be well at the outset to outline in brief the methods employed in seedling selection before considering how the seedlings were obtained. These vary little throughout the period dealt with. The fuzz of the arrows was collected and sown in boxes about December. In any one season approximately 4,000—6,000 seedlings were potted from the boxes in January and February. Then in April following approximately 1,800—2,800 were planted out in the field. During the crop season of the following year (say February—April),

approximately 150—300 were selected in the field, by appearance. Their stools were cut and analysed and 50—100 chosen. The stools of the chosen were dug up, planted elsewhere, irrigated, and in the December of the same year planted in single plots at one Experimental Station.

There, they were given a preliminary test and survivors were planted on an extended scale at several stations with the then existing standard commercial varieties. They were tried for several crop seasons as plant canes and ratoons and repeated eliminations went on until the few good survivors reached the "Select Variety Stage". The "best" of this trial stage were given to planters for trial and if considered good enough, were extended in commercial plantings.

The above is, in short, an outline of the scheme employed and there are only few deviations from this general practice.

The next step is to consider the origin of the seedlings.

For the period under review, viz. 1887-1925, seedlings were always obtained from arrows, the fertilisation of whose flowers was left to the results of chance pollination (referred to as open arrows.)

From 1902-1919, however, the above class of seedlings was supplemented by seedlings derived from one or more methods of controlled pollination. A short account of this work will follow in order to show just in how far seedlings from these methods contributed to the general sowings and pottings made.

The controlled pollination work was started by members of the Imperial Department of Agriculture for the West Indies and later continued by members of the Barbados Department of Agriculture. This work were best considered under two heads, i.e. (1) hybridisation and (2) selfing.

Hybridisation was effected in two ways; (1) by emasculating young unopened flowers of the variety to serve as "female" and pollinating these with pollen of selected "male" varieties. The aims and methods are described in detail elsewhere (4) and need not be repeated here. It is sufficient to state that it is probably of all methods the most reliable when hybridisation is necessary, but at the same time the labour, patience and skill required is perhaps out of proportion to the few seedlings resulting. The seedlings from such crosses were ultimately named B.H. (Barbados Hybrid).

The second method originated in 1902 when the method of open crossing, previously employed by Kobus in Java, was started in Barbados (5). This consisted in the use of varieties which developed little or no pollen as "females" and planting them chessboard fashion with varieties possessing much fertile pollen and eventually enclosing one of the "female" and one of the "male" arrows —one each from adjacent plants— in a bag. The seedlings from this method of crossing were in time designated B. N. H. (Barbados Natural Hybrid). Regarding this method of hybridisation it is reported:— "It is possible that the seedlings thus obtained might be the

"result of self-fertilisation, as sometimes the "female" canes produce a few "normal pollen grains but the chances of self-fertilisation are reduced to a "minimum."

The other form of controlled pollination was self fertilisation. The object of this was stated in the Report "to obtain an idea of the transmission "of unit characters to the progeny and in order to gain some knowledge of "the value of different Barbados seedlings as the starting point for further "work," and again, "the composition of individual plants must be considered "as much by their progeny as by their ancestry." Selfing was carried out in standard commercial varieties and seedlings which had reached "select variety trial" stage. The resulting seedlings were given the symbol, B.S.F. (Barbados Self-Fertilised).

Later, also, selfing was carried out with seedlings derived from artificial and natural hybridisation, since as the Report for 1908-1910 states "in the "next generation (i.e. the F 2) the characters will segregate." Seedlings derived from selfing such hybrids were given a composite designation which included both parent and offspring.

This controlled pollination work was carried out in greater or less amount each year between 1902 and 1919. In any one year, however, the contribution of seedlings from such pollinations was as a rule small compared with that of seedlings from open arrows.

Table I. shows the total number of seedlings potted in any one year and the number planted into the field and the remaining columns show the contributions of seedlings from controlled pollinations to those totals.

(It may be stated here that owing to a certain difficulty in interpreting some of the records, these figures are not complete nor accurate but they are considered sufficiently so for purposes of this part of the investigation).

TABLE I.

SUGAR CANE BREEDING IN BARBADOS 1887-1925.

The Contributions of Seedlings from Controlled Pollinations to the total Number of Seedlings in the Years 1902-1919.

Year.	Total Number.		Artificial Hybrids		Selfed Artificial Hybrids.		Natural Hybrids.		Selfed Natural Hybrids.		Selfed Varieties.	
	Potted.	Planted.	Potted.	Planted.	Potted.	Planted.	Potted.	Planted.	Potted.	Planted.	Potted	Planted.
1902	*	*	–	–	–	–	196	196	–	–	–	–
1904	6,777	*	5	5	–	–	–	–	–	–	6	6
1905	4,874	*	–	–	–	–	–	–	–	–	9	9
1906	219	196	0	0	–	–	0	0	–	–	0	0
1907	4,086	*	12	12	–	–	413§	413§	–	–	421	421
1908	1,705	1,587	4	4	43	43	0	0	–	–	127	127
1909	4,591	2,063	7	7	38	38	235	151	–	–	392	205
1910	6,673	1,966	216	181	55	55	0	0	33	33	767	267
1911	5,538	2,334	0	0	0	0	358	358	7	7	0	0
1912	4,102	*	3	3	0	0	–	–	20	20	2,547	1,483
1913	5,865	2,102	0	0	123	48	384	181	0	0	1,050	492
1914	2,127	1,935	0	0	–	–	0	0	–	–	0	0
1915	7,666	2,886	0	0	227	126	0	0	888	300	913	425
1916	6,563	2,579	0	0	1,544	728	372	187	–	–	–	–
1917	4,977	2,724	0	0	972	480	72	27	–	–	–	–
1918	6,069	2,946	–	–	902	496	–	–	–	–	–	–
1919	5,000	2,710	–	–	800	428	–	–	–	–	–	–

*Figures for these were not obtained.

§ This lot probably only contained 13 true hybrid seedlings. Four hundred were derived from B.3746 x B.3675. The former, however, in 1907 produced numerous self-fertilised seedlings.

From Table I, it is seen that the number of artificial hybrids obtained in any season was exceedingly small, with the exception of 1910. In this year approximately 10% of these seedlings occupied the total field plantings. It is interesting to note that the famous variety B.H. 10 (12) was included in this lot. One other plant only—B.H. 10 (74)—reached select variety standard, but it was soon discarded.

It is only fair to state that, owing to the fewness of seedlings obtained and tried by this method, it is not surprising that so few got any length in the selections.

The selfing of hybrids derived from the artificial hybridisation process does not appear to have given any seedling of note. It was not, however, until 1915, that the members of this method were given a fair representation and from 1915-1919 all of these were selfs of one parent plant—B.H. 10 (12). This plant from recent experience is known to give very poor seedlings when selfed and it is considered that, perhaps, better results might have been obtained if a greater number of parents of known hybrid origin had been tested.

The number of seedlings from natural hybridisation planted in the field is seen to be small and the fact that only two—B.N.H. 02 (5) and B.N.H. 11 (6)—appear to have reached "select variety" stage is not surprising.

Selfings of natural hybrids were only tested on a reasonable scale in 1915 when approximately 11% of the first year field population was planted with these selfings. Two of these—B.N.H. 11(6)/15(4) and B.N.H. 11(6)/15 (2)—reached select variety stage but were soon eliminated.

Seedlings from "selfed" varieties contributed by far the greatest percentage of seedlings from controlled pollinations to the total first year plantings, but even here, their percentage representation in the first year population was never very high.

The years 1912 and 1913 saw their highest representation and it is interesting to note that seven and three members respectively reached "select variety" stage. The lot, moreover, selected in 1912 persisted in the latter trials for several years although they never reached the stage of plantation planting.

To recapitulate in brief the results of the Barbados work in controlled pollinations it may be said that with the exception of B.H.10(12), no good variety emerged, but that, having in view the comparatively small number of seedlings from controlled pollinations tried and, in the case of selfings, the fewness of the parent plants employed, the results are perhaps to be expected.

Having considered the results of controlled pollination, the remainder of this investigation may be devoted to a study of the work on the derivation of seed from open arrows, the subsequent selections and the results of this work. As was stated previously, the majority of seedlings raised throughout the period 1902-1919 were from open arrows, while before and after these dates up to 1925 sowings were made entirely from open arrows.

It is obvious that seedlings from these arrows may, where the variety is hermaphrodite, be selfs or crosses, or where the variety is male sterile, be crosses only.

The records for any one year do not state the number of seedlings of each parent variety in the first year population. Hence it is impossible to arrive at any definite conclusion as to the value of any parent employed. This, because it is held that the greater the number of seedlings of any one parent grown in first year population, the greater the chance of further selection of seedlings of that parent, and it is on the *percentage* selection of the total number of its seedlings planted in a first year population that the value of a parent plant is judged.

From 1910 onwards, the records indicate the number of seedlings of each parent selected in the first year. Here again, however, the total number of seedlings of each parent planted is not indicated. Thus the percentage field selection of seedlings of each parent cannot be determined.

The investigation is, in this part, solely confined to enumerating the parent varieties employed, their origin, and the evolution of all those seedlings produced over the period, 1887-1925, which reached the "select variety" stage.

Two Tables were drawn up as a result of the investigation. The first is a record of the parent plants employed in breeding in Barbados from about 1903 to 1925. Prior to 1903, the parent plants are not mentioned. The parent plants are listed for the years in which they were employed and from 1910—1925 a note on the number of selections in the first year is made for each parent. The data is presented below in Table II. (Only those parents which had one or more seedlings selected at the first year reaping are noted in the records, but it is considered that, despite this fact, the majority of the parents employed are listed here).

TABLE II.

LIST OF THE RECORDED PARENT VARIETIES AND THE YEARS IN WHICH THEY WERE EMPLOYED.

(The figures in brackets after parent symbols from 1910 onwards, denote the number of seedlings from those parents selected for a second trial).

Year.	Parent Plants Employed.
Up to 1905.	D.74, D.95, D.130, T.24, White Transparent, Ribbon, Jamaica Cane, B.208, B.347, B.521, B.535, B.620, B.645, B.647, B.973, B.1280, B.1283, B.1355, B.1360, B.1376, B.1378, B.1379, B.1496, B.1529, B.2133, B.2510, B.3289, B.4993.
1906	B.1030, B.1233,. B.1462, B.1719, B.3208, B.3211, B.3207, B.3718, B.3747, B.3874, B.4347, B.4955, B.4993, B. 5035, B.5102, B.5108, B.5183.
1907	B. 208, B.1233, B.1719, B.3209, B.3211, B.3819, B.3922, B.6048.
1908	B. 208, B.376, B.1529, B.3696, B.6048, B.7191.
1909	B.1030, B.3405, B.3390, B.3412, B.3675, B.3746, B.3747, B.3819, B.3871, B.6048, B.7627.
1910	B. 208 (2), B.374 (2), B.3838 (1), B.6308 (1), B.6341 (7), B.6346 (1), B.6381 (3), B.6388 (2), B.6450 (3), B.6835 (68), B.7169 (2), B.16536 (9), B.18214 (1).
1911	B.208 (1), B.3922 (1), B.3859 (1), B.6450 (1), B.6835 (49), B.16536 (10).
1912	B.208 (2), B.3922 (2), B.6308 (10), B.6450 (28).
1913	B. 4578 (2), B.6308 (2), B.6388 (8), B.6450 (17), B.6835 (17), B.7169 (4), B.18208 (2), B.18214 (3) Ba..4411 (2), Ba.6003 (4), Ba.6032 (3).
1914	B.6450 (16), Ba.5930 (56).
1915	T.24 (3), B.6388 (2), B.6450 (22), B.7169 (13), Ba.5930 (14), Ba.6032 (4), Ba.7924 (8), Ba.9896 (2), Ba.11266 (5).
1916	B.6308 (4), B.6835 (29), B.7169 (2), Ba.6032 (10), Ba.7924 (25), Ba.9855 (8), Ba.11403 (1), Ba.11569 (4), B.H.10 (12) (18).

TABLE II—*Continued.*

Year.	Parent Plants Employed.
1917	B.6450 (10), Ba.6032 (12), Ba.7924 (14), Ba.11569 (39), B.H.10(12) (18).
1918	B.6308 (2), B.6450 (1), Ba.6032 (8), Ba.7924(10), Ba.11569 (15), B.H.10(12) (27), Ba.12079 (7), Ba.13554 (6).
1919	B.6450 (24), Ba.7924 (5), Ba.11569 (24), B.H.10 (12) (1), Ba.11224 (5), B.60(5).
1920	Ba.6032 (34), Ba.7924 (2), Ba.12079 (1).
1921	B.6450 (6), Ba.6032 (2), Ba.7924 (26), Ba.11403 (3), Ba.11569 (9), B.H.10 (12) (8), Ba.12079 (17), Ba.11224 (12).
1922	Ba.6032 (11), Ba.7924 (9), Ba.11569 (78), B.H.10(12) (2), Ba.12079 (12), Ba.11224 (1), B.67 (9).
1923	Ba.6032 (11), Ba.11569 (21), B.H.10(12) (6), Ba.12079 (31), B.417 (2).
1924	Ba.6032 (4), Ba.11569 (80), B.H.10(12) (17).
1925	B.6450 (6), Ba.6032 (1), Ba.11569 (29), B.H.10(12) (2), B.374 (2), B.391 (5), B.417 (2), B.~~450~~ 405 (1), S.C.12 (4) (1).

The above table presents several points of interest. Up to 1905 the predominant parents—if one can judge by the number of seedlings selected from each after one year's growth—were D.74, D.95, B.208 and T. 24. The first two are seedlings of White Transparent but the parentages of B.208 and T.24 are unknown. Later it will be shown that most of the Barbados seedlings of note can be traced to those varieties.

It is worthy of note that in each of the years from 1906 to 1910, new parent varieties were used. There are very few notable exceptions to this. B.208, B.3747, B.3922 and B.6048 are the best examples. In 1906 there was no predominant parent. In 1907, B.208 and B.6048 predominated. In 1908, no parent predominated. In 1909, B.3390 and B. 7627 furnished the majority of the selected first year seedlings, while B.6835 did this in 1910.

From 1910 onwards, it appears that, contrary to previous years, parent varieties were given longer trials to prove their value as seedling producers. Thus, B.6835, B.6450, B.6388, B.6308, B.7169, Ba.6032, Ba.7924, Ba.11569,

B.H.10(12), Ba.12079 and Ba.11224 all had sowings made for at least three years. The most notable in this respect were B.6450 (eleven years), Ba.6032 (eleven years), Ba.7924 (eight years), Ba.11569 (nine years) and B.H.10(12) (nine years).

This change in the short time of use of many parents to the longer use of fewer is best noted by the fact that from approximately 1901—1909, fifty-eight parents were employed, whereas from 1910–1924 only thirty-five were used.

The data from this table will be referred to again in the discussion.

The next consideration is the origin and time of origin of "promising" seedlings. A "promising" seedling is one which has tried for several years in the "select variety" trials. These trials were the last in the selection sequence, prior to liberating any variety for planting on the estates.

These are listed in Table III.

TABLE III.

SUGAR-CANE BREEDING IN BARBADOS 1887–1925.

LIST OF "PROMISING" SEEDLINGS BRED IN BARBADOS WITH THEIR YEAR OF FIRST SELECTION AND THEIR PARENTAGE.

Seedling.	Parent Variety or Varieties.	Year of First Selection.
Burke	Unknown.	Before 1904.
B.109	,,	,, ,,
B.145	,,	,, ,,
B.147	,,	,, ,,
B.149	,,	,, ,,
B.156	,,	,, ,,
B.208	,,	,, ,,
B.347	,,	,, ,,
B.373	,,	,, ,,
B.376	,,	,, ,,
B.379	,,	,, ,,
B.390	,,	,, ,,
B.393	,,	,, ,,
B.1355	D.74	,, ,,
B.1521	D.95	,, ,,
B.1529	D.95	,, ,,
B.1566	D.95	,, ,,
B.1753	Unknown.	,, ,,
B.3390	D.74	,, ,,
B.3405	D.74	,, ,,
B.3412	D.74	,, ,,
B.3675	D.95	,, ,,
B.3696	D.95	,, ,,
B.3747	D.95	,, ,,
B.3859	D.95	,, ,,
B.3922	B.647	,, ,,
B.4578	B.521	,, ,,
B.4596	B.521	,, ,,
B.4844	Jamaica Cane	,, ,,
B.4934	B.620	,, ,,
B.5062	D.74	,, ,,
B.5353	D.95	,, ,,
B.6048	D.95	1904
B.6171	B.2510	1905
B.6204	B.2510	,,
B.6292	T.24	,,
B 6308	T.24	,,
B.6388	T.24	,,
B.6450	T.24	,,
B.6835	B.1379	,,
B.7169	T.24	,,
B.8860	D.95 x B.208	,,

TABLE III.—*Continued.*

Seedling.	Parent Variety or Varieties.	Year of First Selection
B.12791	B.1233	1908
B.12619	B.1233	„
B.14761	B.3208	„
B.16186	B.208	1909
B.16536	B.208	„
B.18208	B.3819	„
B.18214	B.3819	„
B 17380	B.6048	„
Ba.597	B.3405	1911
Ba.2471	B.3390	„
Ba.6032	B.7169	1912
Ba.7924	B.6835	„
Ba.8069	B.6835	„
Ba.8409	B.6835	„
Ba.8846	B.6450	„
B.H.10(12)	B.6835 x B.4578	„
Ba.11403	B.16536	1913
Ba.11224	B.6835	„
Ba.11569	B.16536	„
Ba.12079	B.16536	„
Ba.12652	B.6450	1914
Ba.13378	B.6450	„
Ba.13154	B.6450	„
Ba.13732	B.6450	„
Ba.13781	B.6450	„
Ba.13853	B.6450	„
B.S.F.13 (8)	B.6450	1915
B.S.F.13 (14) ..	B.6450	„
B.18	B.6450	„
B.39	B.208	„
B.67	B.6835	„
B.76	B.6450	1916
B.85	B.6450	„
B.117	Ba.5930	„
B.268	Ba.7924	1918
B.374	Ba.12079	1919
B.381	Ba.11569	„
B.391	Ba.11569	„
B.417	B.6835	„
B.465	Ba.11569	1920
B.472	Ba.11569	„
B.606	B.6450	1923
B.663	Ba.11569	„
B.689	B.67	1924
B.693	B.67	„
B.702	Ba.6032	„
B.726	Ba.11569	„
B.755	Ba.11569	„
B.891	Ba.11569	1925

With the aid of the two tables a chart has been drawn up. This chart is so arranged as to include all the varieties contained in the tables and to reveal their origin—where possible. Four types of varieties may be distinguished in these genealogies. (It must be borne in mind that, in almost every case the female parent only of any variety is known, and that, so far as varieties, apart from their use as parents, are considered, only those which reached "select variety" stage are presented. This latter treatment, therefore, omits all those seedlings which were discarded before reaching the "select variety" stage). There are presented (1) varieties used as parents only, i.e. they themselves were not included in "select variety" trials, (2) varieties which went so far as to be included in "select variety" trials, but which were not, or at most, only little employed as parents, (3) varieties which reached "select variety" stage and were also used as parents and (4) varieties which were grown to a greater or less extent on a commercial scale on plantations.

Owing to the considerable size of this chart, it is impossible to present it in full here. A survey of the chart, however, reveals that there are five breeding "lines" which are definitely outstanding, that is to say, their numbers have been considerably exploited as parents and from them the majority of the successful seedlings have evolved.

These "lines" are presented in Table IV.

TABLE IV.

"LINE" I.

White Transparent**†

D.74

B.1030 B.1233 B.1283 B.1355** B.1376 B.1462 B.3405**† B.3390** B.3412**† B.3289 B.5062* B.5102 B.5108

B.12619* B.12791*

Ba.597* Ba.2471* Ba.4411

"LINE" II.

White Transparent**†

D.95**

B.1529** B.1521* B.1566* B.3696** B.3675** B.3718 B.3746 B.3747** B.3819 B.3838 B.3859** B.3035 B.5183 B.5353* B.6048**

B.18204* B.18214*

"LINE" III.

T.24 (Parent Unknown.)

B.6292* B.6308**† B.6341 B.6346 B.6381 B.6388** B.6450**† B.7169**† B.7191

Ba.6032**† Ba.6003 Ba.5930

B.117* B.131*

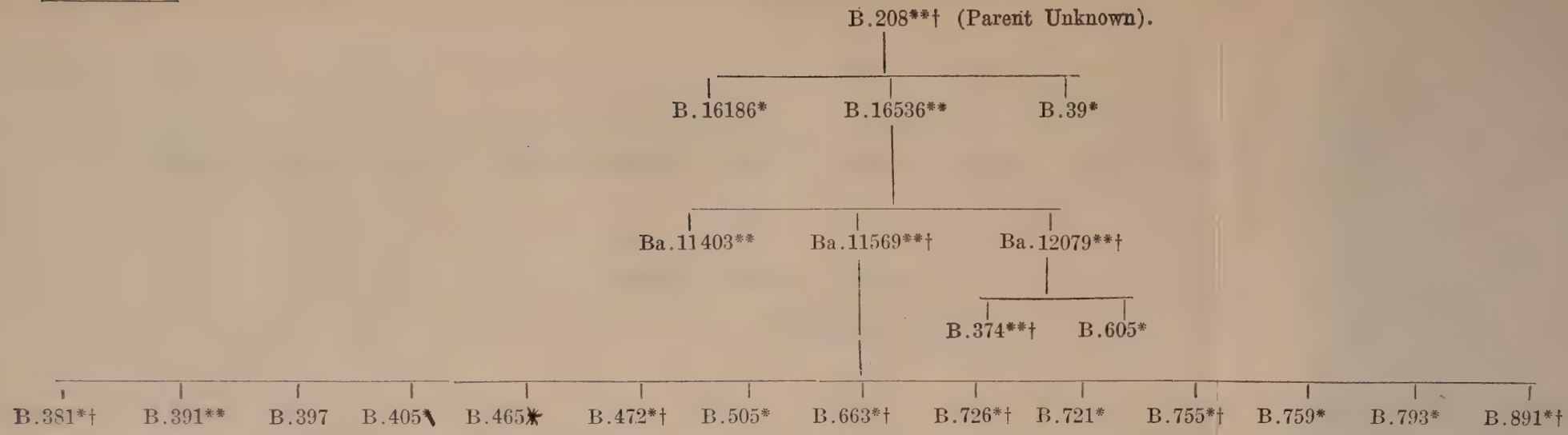
B.585* B.603* B.612* B.613* B.702*

Ba.8846* (Ba.12652* Ba.13378* Ba.13154* Ba.13732* Ba.13781* Ba.13853* B.S.F.13(8)* B.S.F.13(14)*) B.18* B.76* B.85* B.606**†

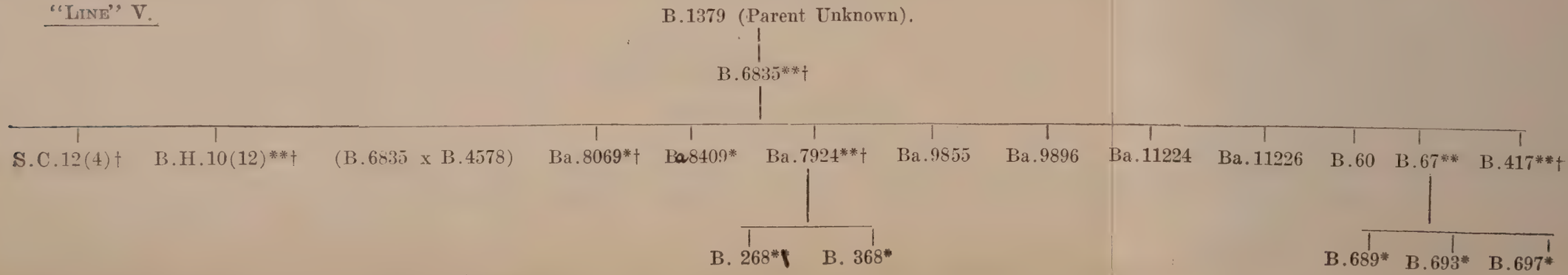
These are all from "selfings" of B.6450 made in 1912 and 1913.

TABLE IV.—*(Concluded).*

"Line" IV.



"Line" V.



(S.C.12(4) was a Barbados seedling included in a consignment of seedlings in the box stage sent to St. Croix and selected by Dr. Longfield Smith in that island.)

THE OUTSTANDING "LINES" IN BREEDING.

(NOTE: Where no sign occurs after a variety symbol then that variety was used as a parent only; where one star is present, it indicates that the variety was included in select variety trials but was not, or at most very little used as a parent: where two stars are present, then that variety was grown as a select variety and also used as a parent: wherever a cross is present the variety was planted to a greater or less extent on a commercial scale).

DISCUSSION.

The standard canes in Barbados prior to commencement of sugar cane breeding were in order of time Creole, Bourbon and White Transparent. In the Report of the Sugar Cane Experiments for 1888 appears a list of thirty-nine varieties imported and being tested. Doubtless, many of these thirty-nine were synonymous, but they, with the abovementioned three varieties, represent the possible foundation stock of the Barbados seedlings. Additional cane varieties were afterwards imported, but although a few were used in breeding, no seedling of merit was derived from them.

Table IV shows the five "lines" along which appear by far the greater proportion of the total number of successful seedlings.

Indeed, at the present day there are no survivors from the other "lines," either as parent or plantation varieties.

This simplifies the problem into a consideration of those "lines".

The first two "lines" originated in White Transparent. D.74 and D.95 were largely employed for the production of seedlings up to 1905. Neither seems to have been very successful in furnishing good seedlings or good parents and the use of the varieties in both "lines" was discontinued comparatively early in the period under review. They have to-day in Barbados only historical interest, and neither is in use in the present day work.

Lines III, IV and V, however, have persisted up to the present day and seedlings from each are being planted commercially and are in use as parents. It is unfortunate that the parents of the foundation seedlings of these "lines" are unknown. It is highly probable that each parent was one of the original sugar cane varieties. Thus a genealogical link in the table is missing from each.

In Line III, originating in T.24, the outstanding parent canes are B.6450 and Ba.6032. It is worthy of note that each has been largely planted on a plantation scale.

Line IV, originating in B.208, has been highly successful in producing good commercial seedlings and good parents. The good parents in this "line" are B.16536, Ba.12079 and above all Ba.11569. It can be safely said that the last has produced all the recent successful seedlings. The fact that this is so may be due to its almost complete male sterility. This will be referred to later.

In Line V the outstanding parent is B.6835. It is sufficient recommendation of its value as a parent to note that this plant has produced such varieties as B.H.10 (12), S.C.12 (4) and B.417.

It now remains to consider in how far the results of this investigation may be applied to the present day scheme of work in breeding.

It may be stated here that, with little exception, the present method of obtaining seedlings is by controlled hybridisation. In brief the following broad classes of hybridisation are being effected:

(1) beween Barbados varieties;

(2) between Barbados varieties and Javan varieties of the Glagah and Chunee nobilisations;

(3) between Barbados varieties and resulting crosses from the above;

(4) between Barbados varieties and Indian varieties of the Co. series;

(5) between Barbados varieties and Noble varieties originating in Java, Queensland and Demerara.

The first class concerns this investigation. Referring back to the history of the breeding work, it is seen that very early on, the original varieties were discarded in favour of seedlings for seedling production. The reason for this may be that according to workers around that time, seedlings were more prone to arrow than original varieties and also the fertility of seeds from seedlings was greater than from those original varieties (6). This is perhaps a little unfortunate in that a certain amount of variability in the progeny— a desirable feature— may have been lost. Harrison wrote that "while the seed-"lings of the older varieties with but few exceptions show marked tendency "to variation, the seeds obtained from seedling varieties do not possess this "property to anything like the same extent, and in many of them the offspring "appears to come fairly true to parentage." Perhaps the reason for this is that probably many seedlings derived from open arrows are "selfs" and they really represent steps towards the establishment of pure lines. It might then be useful to breed some of our present day seedlings back to original varieties.

The breeding in Barbados has in the main been done with varieties of five "lines" and it is possible that selfing is taking place to a great extent in those varieties. This appears to find support to-day in that the surviving varieties within "lines" tend to have appearances in common.

It is considered that any further selfing or collecting of open arrows would tend to restrict a desired extensive variability in the progeny, and for this reason crossing has been resorted to. It is not unlikely that the recent success of Ba.11569 as a parent plant, was due in part to the majority of its seedlings being of hybrid origin, owing to its own considerable male sterility.

It is perhaps reasonable to expect that controlled crosses between varieties of different "lines" are more likely to succeed than crosses effected between varieties within "lines." That this is so is supported by the data of the mean weights of seedling populations derived from Barbados—Barbados crosses in 1931. The Tables cannot be presented here but may be referred to (7). There it is seen that crosses between Ba.11569 and "male" parents in other "lines" give seedling populations with higher mean weights than crosses between Ba.11569 with "male" parents in its own "line."

Following on these findings, it is the intention—so far as Barbados—Barbados crossings are concerned to hybridise between members of different "lines" and to re-introduce into the breeding work some of the older varieties which in the past have performed so well, but which were lost to Barbados before the recent re-organisation of the breeding work.

REFERENCES.

(1) Bannier, J. P., (1926) De Rietveredeling Aan Het Suiker-Proefstation Te Pasoeroean; Techniek, Richting en Resultaten Van 1893-1925 ~~in~~ Arch. v.d. Suikerindustrie in Ned.-Ind. No. 19.

(2) Posthumus, O. (1928) Improvement of Sugar Cane at the Experiment Station for the Java Sugar Industry at Pasoeroean, 1926-1928, inclusive.—Arch. V.D. Suikerindustrie in Ned.-Ind. No. 21 (Translation.)

(3) Barbados Department of Agriculture—Reports on the Results of Field Experiments at Dodds Expt. Station (1886-1889).
Annual Reports on Agricultural Experiments. Part III. Experiments with Seedling and Other Varieties of Cane (1901-1925).

(4) "Artificial Cross Fertilisation"—J. P. d'Albuquerque, in a communication to West Indian Agricultural Conference (1905), W.I. Bull. V, pp. 361-363.

Stockdale, F.A. (1906)—"Improvement of Sugar Cane by Selection and Hybridisation" W.I. Bull., VI, p. 394.

(1907)—"Breeding Hybrid Sugar Canes," W.I. Bull., VIII, p. 79.

(5) Lewton-Brain, L., (1904)—"Hybridisation of the Sugar Cane," W.I. Bull., IV, p. 63.

(6) Harrison, J. B. and Jenman—(1904) "Sugar Cane Experiments at British Guiana (1896-1902)" Resumé in W.I. Bull., IV., p. 58.

(7) McIntosh, A.E.S., (1930)—Report of the Department of Science and Agriculture, Barbados, 1930-31, Chapt. II pp. 28-32.

A SURVEY OF THE POSITION OF PHYTALUS SMITHI, ARROW, AND ITS NATURAL ENEMIES IN BARBADOS.

By

R. W. E. TUCKER, M.A., B.Ed.

In the latter half of 1928 the writer made a general survey of the principal insect pests of sugar cane in Barbados, to determine the economic status of each in order to organise work for their control. The position of *Phytalus smithi* or brown hard back, was summed up from past records and publications, and from information obtained from plantation managers, etc. as being of minor importance compared with *Diatraea saccharalis* and *Diaprepes abbreviatus*, and it was decided that the measures adopted to control *Diaprepes* would also in time control *Phytalus*.

It does occasionally happen, however, that the extent of infestation due to an insect is not fully realised until attention is centred on it, and then reports of its presence begin to pour in from people who had previously disregarded it and from areas where previously it had not even been noticed.

Thus the centering of attention on the organised collection of adults of *Diaprepes* and *Phytalus* aroused three alarms, namely that the parasite *Tiphia parallela* which had been reputed to control *Phytalus* in the past, had now disappeared, that the numbers of *Phytalus* were increasing rapidly, and finally that it was spreading to new areas of the island.

The first point, namely the apparent disappearance of the parasite *Tiphia* led to the indictment of the so-called Dr. Morris bird *Tyrannus dominicensis*, and to a demand for its extermination. This matter was investigated by the writer, and the results published in Tropical Agriculture, Vol. VII, No. 3, pp. 68—69, the conclusion having been reached that there was no evidence on which to condemn the bird, but that there was evidence that it fed extensively on pest insects of cane.

The second point namely that the numbers of *Phytalus* were increasing rapidly was no doubt due to the fact that this pest is more seasonal than *Diaprepes* and that when the rains begin, large numbers emerge all at once, usually early in June, very soon after the first rains: consequently not only are houses and gardens invaded, but collectors who should bring in *Diaprepes* bring in mainly *Phytalus*, and for a period of some weeks, millions are collected. Hence, having to pay for their collection, planters are convinced that there are more than ever there used to be.

The third point, namely that the pest is spreading to new areas of the island, may possibly be as correct as the view that no one has seen it there be-

fore because they have not looked for it. It is quite possible, that, as with *Diaprepes*, a series of dry years has caused the pest to spread into the higher, rainier areas of the island; there is, however, no evidence in Mr. B. A. Bourne's detailed work on *Phytalus smithi* published in Barbados Departmental Report 1919—20 to show that the beetle is repelled or handicapped by the relatively slight differences in rainfall and soil moisture between the coastal and central areas of the island. The evidence is rather that excessive soil dryness is more detrimental to the deposition and hatching of the beetles eggs than moderate wetness of soil, and that when laid, the eggs are not necessarily damaged even by flooding. There would also not appear to be any radical difference between the soil composition, as shown by recent surveys, to limit the spread of either *Phytalus* or *Diaprepes*.

The question therefore as to whether it is spreading owing to diminished rainfall or whether it is thought to be spreading because it is now being more carefully observed by planters, must be left open; it can only be determined by lengthy and detailed work on this pest and so far its economic status and the need to carry on other more important work, has not enabled such detailed work to be carried out.

A certain amount of data has, however, been obtained, and with this, and the Departmental records of observations on this pest and its parasite *Tiphia* during the past twenty years, it is possible to survey the position of *Phytalus smithi* and of its natural enemies in Barbados.

The first records are those of Mr. W. Nowell in 1911-12, when the presence of a Scolid parasite of the brown hard back grubs was reported. The effect of this parasite was then thought to be considerable, though it would not appear that examination of the parasite and pest relationship was made in more than a few localities in a limited area. It would appear also that occasional noticeable increases in the numbers of beetles were evident at that time.

In 1912-13 *Phytalus* grubs newly parasitised by *Tiphia parallela* were found sparingly in February and March, showing that some adults were flying at that season; a few adults were also seen in April, whilst from early June to early November adults were seen in abundance. The life cycle and habits of this parasite were carefully observed at this period by Mr. Nowell, and large numbers were collected for shipment to Mauritius. Parasitism would appear to have been irregular, varying apparently from 0% to 100% per stool, with an average at that period and locality of about 30%. It is stated however in this account that "unfortunately little is known as to the distribution of *Tiphia* in" "the island, but that it is localised is shown by the fact that a noticeable out-" "break of *Phytalus* at Waterford Plantation this year attracted very few" "*Tiphia*. There is some evidence that a similar outbreak occurred at the north-" "ern border of Spencers and adjoining lands of Hopefield three or four years" "ago, and probably the abundance there of *Tiphia* at the present time is thus to" "be accounted for. An attempt has been made to hasten the increase of *Tiphia*" "at Waterford by transferring adults, cocoons and parasitised grubs from" "Spencers."

It may be mentioned that Waterford in the parish of St. Michael is only about ten miles across open country planted to cane and to leeward of the area where *Tiphia* was then abundant.

In spite, however, of the determined effort to colonise *Tiphia* at Waterford it is reported in 1913-14 that satisfactory results were not obtained, and that nothing is known of the occurrence of *Tiphia* in any other parts of the island than those mentioned (i.e. Plantations Spencers and Hopefield in the parish of Christ Church).

It is also stated in the same Report that by no means as much *Tiphia* was obtained that year as during the former year, for Mauritius, but that judging from the number of *Phytalus* larvae obtained that year compared with the previous, there seemed to be *an increase of the latter*; further, comparatively few adult *Tiphia* were seen anywhere.

The suggestion is then made that the diminution in the prevalence of the parasite is due to its having first reduced the numbers of its host, followed by a reduction in its own numbers and the resultant increase again of the host together with a decrease in the rate of parasitism found. This explanation does not however seem altogether tenable for there is no evidence of a diminution of the host; on the contrary it is recorded as steadily increasing in numbers and extent.

The Report further states that in the Parish of St. Michael in 1913 there was a very noticeable increase in *Phytalus*, but that a very great effort was being made to establish *Tiphia* there that year.

This apparently failed, and it is moreover stated in the 1914-15 Report that "there was evidently an increase in numbers of *Phytalus* and a decrease of" "its parasite *Tiphia parallela*." As far as can be ascertained observations were limited to the parishes of Christ Church and St. Michael, and the borders of St. Philip, in which region there is nothing whatever that human observation can detect, to prevent the spread of *Tiphia* with its host. The parasite feeds principally on honey dew secreted by aphis on Sorghum, Indian corn etc.; adults have also been captured from castor oil plants, scale infested guava bushes and potato slips; they have not been seen however to feed on or frequent flowers; there should, however, be no lack of natural food for the parasite to which its failure to become widely established could be attributed.

Throughout the period so far reviewed, there is no mention made of attacks on *Tiphia* by *Tyrannus dominicensis*, which in view of the abundance of the parasite in one locality for nearly two years, and the interest taken and close observations to which it was subjected, would surely have been apparent to those undertaking investigations. There is moreover no record whatever of the parasite being prevalent, or even noticed elsewhere in the island, although an appeal was made for anyone noticing *Tiphia* to report the occurrence.

From the Reports of 1915-17, it would appear that at this period the hand collection of *Phytalus* adults and larvae was commenced, mainly on experimental plots at Codrington and Dodds, and such records as there are of *Tiphia* show that it never again became plentiful, and has apparently never at any time exercised any appreciable control. On the contrary, every Departmental Report from 1917 onwards records an increase in *Phytalus* and of *Diaprepes*, and of the damage caused by them.

It would appear, however, that the increase of *Diaprepes* was more rapid and that it was soon recognised that the larvae of *Diaprepes* were responsible for the major portion of the increased damage annually reported.

Thus in the 1917-18 Report it is stated that "the injuries caused to the" "sugar cane by the root borer *Diaprepes abbreviatus* and the brown hard "back *Phytalus smithi* are increasing in intensity in certain areas of the island" "where little or no effort has been made in the past to destroy the egg batches" "and mature insects of the former, and the mature insects of the latter ....." "the areas attacked are being gradually extended."

At this period the idea of taking legislative action to compel collection, was rejected; advisory leaflets were however prepared and circulated among the planters.

Collecting of adults and of grubs was maintained on Government plots, as it was recognised that "the injury done by the two pests is rendering the results" "of the manurial experiments carried on for the benefit of the sugar industry" "practically valueless"; and that "the attacks of these pests are seriously handi" "capping the work of the Department of Agriculture in obtaining new varieties" "of sugar cane." These perfectly justifiable observations gain still greater force when the damage wrought by the moth borer *Diatraea saccharalis* is included.

In the year under consideration, the collection of root borer and hard back grubs from the manurial plots at Dodds gave an average of 1,497 *Diaprepes* larvae and 3,386 *Phytalus* larvae per acre.

In the following year 1918-19, 4,646 root borer larvae and 1,260 hard back larvae, pupae etc. were obtained per acre by digging over the manurial plots at Dodds, whilst in the seedling canefields, a total of 15,681 root borer larvae, and 16,677 brown hard back larvae were obtained. These figures show that at that period brown hard backs were if anything more plentiful than root borers.

Moreover, in this year, counts were made of *Tiphia* cocoons etc. found; and in the manurial plots, the average parasitism was 5.2% and in the seedling plots 4.8% ; in the latter case, parasitism was evidently very irregular, for the number of *Tiphia* found varied from 0 to 1,089 per acre. It can be seen, however, that the average parasitism is not of a high order, although as in 1911-12, a small highly parasitised area might be found which would create a favourable impression.

In this same year it is reported that "the two beetles are gradually spread-" "ing from the low lying districts to the central parts of the island and their" "attacks are no doubt increasing in severity as time goes on. In some instances" "the loss occasioned by these pests has reached during the year under review as" "much as 50%."

In the sugar cane report of Barbados for 1917-19 it is stated that the number of larvae of *Phytalus* found was one-third the number of *Diaprepes; Phytalus* therefore causes about one-fourth of the loss due to both insects, and this loss is estimated at that period at a minimum of 4.36 tons of cane per acre.

At about this period Mr. B. A. Bourne, the Assistant Director of Agriculture, carried out an extensive investigation of the life history, etc. of *Phytalus smithi* under Barbados conditions, and an excellent and comprehensive report on his work and recommendations is published in the Departmental Report for 1919-20.

During 1919 moreover, a Commission took evidence in Barbados on the root borer and brown hard back, a full Report, with recommendations, being published that year.

In this Report it is stated that "Although *Tiphia* is well established in" "Barbados, and appears to be an active parasite of *Phytalus smithi* it does not" "control the brown hard back sufficiently to prevent its spreading and greatly" "increasing in numbers"; and again "The parasite *Tiphia parallela* is present" "and exerts some control though at present this is quite inadequate."

No action following the work of the Commission appears to have been taken however and from 1920 to 1928 each Departmental Report contains the same remarks namely, no improvement in the situation, and both pests increasing.

The last recorded statement on the status of *Tiphia* as a parasite of *Phytalus* is that made by Mr. Bourne in the 1919-20 Report, in which he says "At the" "present time this parasite does not seem to be effectively keeping their numbers" "from increasing in some localities, and although they are doing much good, yet" "it is quite probable that adverse weather and other conditions and possibly" "some unknown parasite are hindering their activity somewhat."

There are no further records to be found on the distribution or effectiveness of *Tiphia* and it must be admitted that the evidence so far is not that a successful or widely spread parasite in the shape of *Tiphia* has gradually become extinct. It cannot be said at the present juncture whether this parasite is still apparently limited in its distribution to a portion of the Southern end of the island or whether it still ebbs and flows, with occasional bursts in limited areas, because to investigate the host parasite complex effectively over the whole island and to make any material advance beyond the knowledge already available would be a whole time project, and, apart from the difficulty of fitting this in, the records of *Tiphia* do not appear sufficiently promising to justify making it a full time project. It would, however, be a very interesting subject for investigation.

Watch has been kept from time to time on *Phytalus*, and the results have confirmed the idea that as a pest it is quite secondary to *Diaprepes*, and that *Tiphia* is very rarely observed either in the soil stages or in the adult stage.

With regard to the relative prevalence of *Phytalus*, the adults emerge annually in great numbers over a short time, and as stated disturb the equanimity of some people. Unfortunately, in the returns of beetles collected by planters, distinction is not always drawn between *Phytalus* and *Diaprepes*, but in June, 1931, separate records were sent in of 1,226,800 brown hard backs and 4,515,900 root borers, though it is possible that the latter figure also includes many hard backs.

No further records, after the June emergences, were received of brown hard backs; whereas the total of root borers collected gradually mounted to nearly eight million. On the estate Lancaster, in the Northwestern area of the island, exact records are kept of the numbers of each kind of beetle, and the results showed 277,000 *Phytalus* and 1,315,200 *Diaprepes* adults collected during the year in 1930, in 1931 the figures were 679,200 *Diaprepes* and 504,800 *Phytalus* collected.

All however show the preponderance now of *Diaprepes* over *Phytalus*.

The other natural enemies of *Phytalus* are insignificant in their total effect. The wasp *Dielis dorsata*, which is parasitic on the black hard back *Ligyrus tumulosus* attacks *Phytalus* occasionally; but the amount of such parasitism is recorded by Nowell as not more than about 1% of that due to *Tiphia*. Bourne also records that Nematodes are found attacking *Phytalus* larvae and eggs under certain conditions, and that a bacterial disease, which could be transmitted to healthy grubs by inoculation, was found to kill larvae in the laboratory; also that green muscardine fungus killed larvae in the field—and might possibly account for the apparent scarceness of the pest in the wetter portions of the island.

It is more than probable that the common toad, *Bufo agua*, is capable of exerting a notable check on *Phytalus*, both at emergence and egg laying periods, and during the daily periods when the beetle returns to or emerges from the soil for the purpose of feeding or mating. This toad should therefore be protected and not destroyed as it often has been in the past.

The total effect of the other controlling agents does not, however, appear to be great, or to warrant serious consideration.

It can be concluded, therefore that there is no evidence to show that *Tiphia parallela* was ever either widely spread in Barbados or effective in its control over *Phytalus smithi;* nor has it ever again occurred in such numbers as it did in a limited locality in 1912. Although the host is recorded as always present in considerable and increasing numbers, and as spreading every year the parasite is recorded as continually decreasing. In spite of careful observations no reason for this decrease could be found.

At the present time, there is no doubt that *Tiphia* is very little in evidence and that as a controlling factor it would appear to be negligible.

The control of *Phytalus smithi* therefore depends on the annual co-operative collection of adults, and the systematic destruction of grubs when cane stools are dug up.

The investigation of the distribution of *Phytalus* and *Tiphia* over the whole island, and of extent of parasitism by *Tiphia*, and the study of host parasite relationship in general, and of the factors, if any, which are limiting the effectiveness of *Tiphia*, would form a most interesting study which, though borne in mind, has not yet been found practicable.

THE SCIENTIFIC CONTROL OF PAN BOILING.

BY

S. J. SAINT, M.Sc., Ph.D., F.I.C.

Since sucrose only crystallises from its supersaturated solutions, it is necessary in order to achieve satisfactory control of the crystallisation process to know, at any given time, the state of saturation of the sucrose in solution. In the boiling of sugar syrups in the vacuum pan a control of the supersaturation of the sucrose in solution enables one to form a sufficient number of crystals, to grow those crystals without further crystallisation and to prevent dissolution of existing crystals.

With the advent of the Zeiss industrial refractometer it has been possible to determine directly the percentage of dry matter existing in the mother liquor in the pan. The supersaturation of sucrose in solution in a cane syrup can be calculated if the dry matter, purity and temperature of the syrup are known. These variables can be equated as follows:—

$$W = \frac{100R}{C_1 C_2 Lt R}$$

where R = purity of syrup; C_1 = saturation coefficient at purity R; C_2 = coefficient of supersaturation; W = water content; and Lt = solubility of sucrose in water at t°C.

Thieme (1) has determined the solubility of sucrose in cane syrups of varying purities and has evaluated the saturation coefficients for cane juices.

It therefore follows that if the purity and temperature of a cane syrup are known, then either the state of saturation of the sucrose in solution or the percentage dry matter can be calculated if one of these is known.

During the past four years a study has been made of the supersaturations of sucrose in cane syrups boiling in the vacuum pan where the concentrations of the mother liquor have been followed with the aid of the Zeiss industrial refractometer. The true supersaturations of sucrose in solution can be calculated only from the true dry matter and the true purity of the mother liquor. Where the pan refractometer is to be used to control the boiling process, it is sufficient if, what may be termed, the "apparent" coefficients of supersaturation, calculated on a basis of optical purities and refractometric dry matter, are determined.

"APPARENT" COEFFICIENTS OF SUPERSATURATION.

(a) *Graining.*

In Barbados the practical pan boiler grains by the "waiting" method. The syrup is concentrated in the pan until the supersaturation of the syrup becomes so great that crystals form spontaneously. The concentration of the syrup is continued until a sufficient number of crystals are judged by eye to be present.

It was found that with a syrup of an optical purity of 85—86° crystals could first be distinguished under the microscope when the "apparent" coefficient of supersaturation was between 1.33 and 1.35. This supersaturation was raised to 1.5 or 1.6 according to whether few or many crystals were required.

(b) *Boiling.*

In the three strike system, the optimum "apparent" coefficients of supersaturation for the mother liquor during boiling, appear to be about 1.15 for the A. strike, and 1.2 for the B. strike. In the C. strike, after the introduction of molasses, the "apparent" coefficient of supersaturation is maintained at 1.2 up to about 50% of the striking volume of the pan. The supersaturation of the mother liquor is then gradually raised until at a height of about 80% of the striking volume, the "apparent" coefficient of supersaturation reaches 1.35 and at a height of 100%, 1.50.

THE CALCULATION OF TABLES FOR USE WITH THE ZEISS REFRACTOMETER.

(a) *Graining.*

The "waiting" process of graining has been discussed elsewhere (2). From both theoretical and practical aspects it must be regarded as a poor method.

In order to obtain a perfectly regular grain it is necessary to induce the syrup to deposit the requisite number of crystals at one and the same time. In order to attain this end, a high supersaturation must be formed suddenly in the syrup. The graining process which most nearly fulfils this condition is the method by which the crystallisation is induced in the syrup by suddenly raising the vacuum. This method is well adapted for use with the refractometer since, with this instrument, a strict control can be maintained of the supersaturation of the syrup.

If the syrup is boiling under reduced pressure and the concentration and temperature of the syrup are known, the pressure can be calculated since the concentration of the syrup, its boiling point, and the pressure are connected variables. For reasons advanced elsewhere (3) it is better to work with pressure or "vacuum" than with temperature when using the refractometer in practice.

In drawing up tables for "shock" graining, graphs for supersaturations of 1.3 and the desired supersaturation should be made showing the relation between "vacuum" and concentration at those supersaturations. Tables are then readily constructed for the use of the pan boiler by interpolation from the graphs. For instance, Table I shows the calculations necessary to evaluate a curve connecting "vacuum" and concentration for a syrup of 84° optical purity at a supersaturation of 1.6. It will be seen that L_t, the solubility of sucrose in water at t°C., can be calculated, since the purity and supersaturation are defined and from L_t, t°C. can be found from sucrose solubility tables. e°C. is the elevation of the boiling point of a cane sugar syrup at the given concentration and given purity. The elevation of the boiling point of cane syrups of different concentrations and purities were determined by Thieme (5). The difference between t° and e° gives the temperature at which water boils at the "vacuum" which is to be calculated.

TABLE I.

Formula $Lt = \frac{R}{C_1 C_2} \times \frac{T}{W}$

$R = 84.$ $C_1 = 0{\cdot}95.$ $C_2 = 1{\cdot}6.$ $\therefore \frac{R}{C_1 C_2} = 55{\cdot}27$

Let T =	87·0	86·0	85·5	85·0	84·5	84·0	83·5
Then W =	13·0	14·0	14·5	15·0	15·5	16·0	16·5
And T =	66·92	61·44	58·96	56·66	54·52	52·5	50·6
$\frac{T}{W}$							
∴ Lt =	370·0	339·6	325·9	313·2	301·4	290·2	279·7
And $t^{\circ}C$ =	81·5	75·0	71·3	68·2	64·5	60·8	57·3
$e^{\circ}C$ =	16·21	15·10	14·6	14.1	13·6	13·2	12·8
∴ $t^{\circ} - e^{\circ}C$ =	65·3	59·9	56·7	54·1	50·9	47·6	44·5
∴ V = c.m.s	57·05	61·1	63·3	64·8	66·4	67·9	69·0

Table II. was drawn up for the shock graining of a syrup of 86° optical purity in which the supersaturation was to be raised to 1·55. The figures were obtained from two graphs connecting vacuum and concentration for supersaturations of 1·3 and 1·55.

TABLE II.

Optical Purity of Syrup = 86·0
Supersaturation raised to 1·55.

Vacuum in Pan.	24½″	25″	25½″	26″
Raise concentration to (= Supersaturation of 1·3)	82·1	81·7	81·3	80·8
Lower Vacuum to	20 ″	20½″	21½″	22 ″
Raise concentration to (= Supersaturation of 1·3)	84·9	84·5	84·1	83·7
Raise Vacuum to (= Supersaturation of 1·55) and charge with syrup.	24½″	25 ″	25 ″	26 ″

Tables such as these were made out for supersaturations of 1.5, 1.55, and 1.6 and syrups were grained according to these tables in a small experimental pan fitted with a Zeiss refractometer. The number of crystals formed were counted and the results indicated quite clearly that the higher the induced supersaturation the greater are the number of crystals formed (4).

(b) *Washing out grain.*

Fine grain can be readily removed from the pan by means of the refractometer and suitable manipulation of the vacuum. The method adopted was to calculate the necessary data for the construction of graphs connecting concentration and "vacuum" for a supersaturation of 1.1 and an undersaturation of 0.95. The graphs are used in the same way as similar curves are used in "shock" graining. In this case, syrup is run into the pan until the supersaturation of the mother liquor is reduced to 1.1; the vacuum is then lowered until the prevailing concentration of the mother liquor will give an undersaturation of 0.95. This can be read off from the table. When the syrup becomes undersaturated the crystals immediately begin to round off and, as soon as the fine grain has disappeared, the vacuum is raised to its original value. The supersaturation of 1.1 is restored and whilst the washing action is immediately stopped, there is no danger at this supersaturation of forming fresh crystals.

(c) *Boiling.*

In the calculation of tables for the boiling of massecuites in the pan, it is necessary to know the purity of the mother liquor at any given time. In order to find these purities, samples of mother liquor must be separated from the massecuite, at various levels in the pan, for analysis. One or two such series of analyses are sufficient because it is found that, since one system of boiling is invariably adopted at any one factory, the purities of the mother liquors for any particular strike taken at the same levels in the pan are similar. The optimum supersaturations at which to maintain the mother liquor at various levels for different strikes have already been defined. Tables can therefore be constructed for the A, B and C strikes to show the concentration which must be maintained at given levels for the normal variations which occur in the vacuum during boiling. Table 3 was constructed in this way for the boiling of a C. strike. At a level of 60 and a vacuum of 26″ the concentration of the mother liquor as shown by the refractometer should be 86.1. If it is greater than this, the supersaturation is too high and more molasses should be admitted; if it is lower than this, the supersaturation is too low and the rate of entry of molasses should be lessened.

TABLE 3.

For Boiling of "C" Strike.

Level of Massecuite in Pan.	Vacuum in Pan.		
	25"	25½"	26"
40	82.9	82.6	82.2
50	85.4	85.1	84.7
60	86.8	86.5	86.1
80	87.9	87.6	87.2
100	89.7	89.4	89.0
Strike at	89.9	89.6	89.2

With the aid of such tables and the Zeiss refractometer, the graining and subsequent boiling of syrups in the vacuum pan can be controlled with precision by persons with no experience of the empirical methods of pan boiling.

References.

(1) Thieme, J. G., Studies in Sugar Boiling. p. 74.
(2) Saint, S. J., Trop. Agric. V. VII. (1930) pp. 3—8.
(3) „ „ „ „ „ V. V. (1928) pp. 279-283.
(4) „ „ „ Ann. Report Dept. of Agric. 1929-30. p. 69.
(5) Thieme, J. G. loc. cit. p. 90.

THE STATUS OF TRICHOGRAMMA AS A CONTROL OF D. SACCHARALIS IN BARBADOS.

BY

R. W. E. TUCKER, M.A., B.Ed.

It is unnecessary to give details of the procedure of mass rearing and liberation of *T. minutum* as a full account covering the methods adopted in Barbados has recently been published (6). Beyond stating that the equipment therein described has been increased from four to eight moth breeding units, and that it is hoped therefore to distribute over 80,000,000 parasites during 1932, no description of technique or crop sampling to determine results will be given. A new method of parasite distribution which has been devised and put into operation for the handling and even and regular distribution of the mass output mentioned above will, however, briefly be outlined.

The principal object of this paper is to examine the status of *Trichogramma minutum* when mass reared and liberated on an organised plan for the control of a pest which has very little alternative host competition, and which is reasonably uniformly distributed over a compact and limited area.

This method of control is now entering its fourth year in Barbados and although the production of a clear cut demonstration of control has been hampered by a year of severe drought which upset all normal conditions and expectations, and has been limited by the comparatively small beginning and gradual growth of the mass breeding operations—a growth which has relied entirely upon results as observed and appreciated by the planting community itself—the work now being carried out in Barbados with *Trichogramma* has definitely passed the experimental stage. Its value and its defects can therefore be more critically examined.

Trichogramma work in general appears to be suffering in certain quarters from a reaction due to excessive optimism, which has led to a corresponding excessive belittling of past and current results and future expectations (5). To this a reply has already appeared (1). It is also suffering perhaps from judgment based on theoretical objections which may not in all cases be applicable.

As far as can be ascertained, the principal objections are (a) that *Trichogramma* is limited in efficiency by its restricted range of operation and its inability to find its host save by random movements; (b) that inasmuch as *Trichogramma* is parasitic on many hosts, and is not purely specific, that the controlling effect of artificial increases in numbers is lessened by dissipation of the parasite's energy and by the overflow of parasite population in unnecessary directions; (c) that inasmuch as there is a large natural mortality of young larvae hatching from eggs, and that only a small proportion (estimated, but not proved, to be 10% or less) survive and reach situations where they may succeed in developing into adults, that *Trichogramma* in killing eggs is

largely ineffective in that at least 90% of the hatchings of these eggs would have died anyway; (d) that the normal or natural parasitism of *Diatraea* eggs by *Trichogramma* in canefields is such that the numbers of *Trichogramma* normally present per acre are so great that the numbers added per acre by mass liberations are relatively insignificant and unable to produce any appreciable effect; (e) that in any case an increase in the percentage of eggs parasitised by *Trichogramma* is not followed by anything like a similar reduction in the percentage or extent, of damage.

The first objection namely inefficiency due to restricted range of operation and inability to find the host save by random movements would, if correct, justify the condemnation of this parasite. It is possible that in the case of some crops such as fruit borne on large trees and certain insects depositing eggs singly and often in inaccessible places, these objections may hold good. The writer, however, wishes to make it clear that the case now to be stated for *Trichogramma* is based on observation of its work in canefields with *D. saccharalis* as the only host and under the climatic and topographical conditions of Barbados; whether the same arguments apply to other crops, other pests, and other climatic or topographical conditions is for the workers in such cases to determine.

Under the conditions in canefields in Barbados the writer's observations do not show that *Trichogramma* is unduly restricted in range, particularly in cane of medium growth, and with frequent periods of light, steady winds. Nor does there appear to be any proof of discovery of host by random movements only in the field; on the contrary, the frequency with which scattered *Diatraea* egg masses are found to be parasitised would indicate a reasonable efficiency in range and ability to find the host.

In any case, the effect of the regular distribution of mass reared parasites now planned, would compensate for any deficiency in this respect on the part of the parasite and largely nullifies this objection, even were it correct or proved, for the conditions under discussion.

With regard to the second objection, this is no doubt valid when the crop to be protected is interspersed with other crops, or with areas of native flora, which may introduce alternate hosts to which *Trichogramma* will be attracted. There would then no doubt occur dissipation of effective work and a drainage of parasite population from the crop to be protected. It should be possible however to organise the extent and time of mass production of *Trichogramma* to remedy this wastage even as the wastage in spraying and dusting operations due to rain or to surrounding uncontrolled sources of infestation, can be economically countered.

In Barbados however the objection loses most of its force inasmuch as the crop to be protected is in cultivation over an entire, but limited area, alternative crops or areas of native flora are relatively insignificant, and the host pest is present continuously, and in such overwhelming numbers compared with alternative hosts, that any dissipation or overflow is comparatively negligible. Moveover, the latter consideration also makes the parasite a specific one to all intents and purposes.

The third objection, or criticism, namely that a minimum 90% mortality in newly hatched larvae, renders the process of killing the eggs by means of

Trichogramma largely ineffective has been given wide publicity and credence. No one would maintain that this natural mortality factor is negligible but the statement that it renders the work of *Trichogramma* largely ineffective cannot be accepted. Presumably the 90% mortality is an average for the whole cane growing season from the time that the canes have eggs deposited on them when the young shoots are sufficiently grown in January to attract moths for oviposition, to the following year when the mature canes are reaped. There is however no proof of such a high average mortality and it would be difficult to obtain a proof over such a long period. The mortality of young larvae is undoubtedly very high, and in fields of newly springing cane, lack of shelter and the sparseness of the host plant ensure that probably even more than 90% of the larvae die or are carried by wind and air currents into surrounding fields about to be reaped, or to other situations where they perish. At other periods of the year, however, it is most probable that considerably less than 90% of the larvae die before entering canes, and the writer would suggest that if one accepts a 90% mortality as a working hypothesis, it is more likely to be an average of about 95% during eight or nine months of the year and about 75% during three or four months. Thus, from January to April, the mortality comes under the higher average; from May to July, and possibly August, under the lower, and from thence onwards, again under the higher. Considering the nature of cane growth, this is far more likely than a continuous average of 90%. During the first period of high larval mortality, pest population level is low in the young canes and there is a correspondingly low to negligible natural parasitism of eggs; therefore even with a very high larval mortality, sufficient larvae survive and initiate infestation in the relatively sparse developing cane. During the final period of high larval mortality, namely when the canes are dense in growth, and ripening and hardening rapidly, pest population level is normally high; natural parasitism is also high: but owing to the high population level sufficient larvae survive to become effective in damaging the soft upper portion of canes, or young suckers. The maximum damage and rise in pest population level however occurs during the three or four months mentioned, when larval mortality is undoubtedly lower, and the receptivity or accessibility of the canes is greatest. This makes a big difference to the status of *Trichogramma* as a controlling agent, because even with a 90% mortality of larvae, it can be shown mathematically that an increase of even 10% in the average rate of parasitism of eggs reduces the host population level by an amount which can hardly be dismissed as negligible, and in Barbados, field records show that the average rate of parasitism by *Trichogramma* has been raised by 15% to 20% at least. With a higher rate of survival of the larvae, during a comparatively short but very critical period of the canes' growth, the results produced by increasing the parasitism of the eggs are correspondingly enhanced.

Moreover, no attempt is made to distribute *Trichogramma* on a large scale when, in the writer's opinion, natural or climatic or mechanical controlling factors are in the ascendancy, i.e. when the crop is very young, and, when nearing maturity. The timing of parasite liberations, method of distribution, and numbers per acre which the writer has now worked out and adopted will be discussed later.

The question of the 90% mortality in newly hatched larvae must be returned to. As stated, for the sake of a working hypothesis, this figure will be accept-

ed as an average mortality. It must be pointed out, however, that in the absence of parasitism by *Trichogramma*, 100% of the eggs produce larvae; that at least is the writer's experience in Barbados. Without *Trichogramma*, therefore, 10% of the gross deposition of *Diatraea* eggs would produce effective larvae, i.e. larvae which succeeded in boring into canes, and which, except for late larval, or pupal mortality, will produce moths. In Barbados, this mortality is low, inasmuch as there are no native larval or pupal parasites, and no evidence at all of introduced parasites (3), (6) and (7) surviving; the mortality from fungi and natural or mechanical causes is low.

There is, however, a natural parasitism of eggs by *Trichogramma* which reduces the number of effective larvae below 10% though as previously pointed out in other publications (8) this natural parasitism lags behind infestation, until the host population level is high, and damage due to infestation is serious. As in all other instances of parasitism, the effective natural work of *Trichogramma* is dependent on Malthus' law of population (2).

It is possible, however, by co-ordinating the time and numbers of parasites liberated from mass breeding centres, with growth conditions, population level, and natural or mechanical controlling factors, to make *Trichogramma* available and effective at periods when it can effectively reduce population level, owing to an increase in the average percentage of eggs killed by parasitism.

It must be borne in mind that but for the parasitism, 100% of larvae would hatch; that the unknown natural factors responsible for the 90% larval mortality would presumably destroy an approximately equal proportion, whatever the population; and that the initial rate of natural parasitism is dependent on initial host population level.

The latter condition is practically indeterminable; almost every pest varies annually in its initial population level due to climatic and other natural factors, many of which we cannot ascertain, and it will only be by an observed reduction in final infestation over a series of years that control can be claimed. This applies to any method of controlling *Diatraea saccharalis*, whether by larval parasites or otherwise.

It can be seen therefore that the argument of a 90% natural mortality of young larvae (*not* eggs) does not render *Trichogramma* as ineffective as one would be given to understand.

The fourth objection, briefly put, is that the numbers of *Trichogramma* made available by mass breeding and liberation are insignificant when added to the total numbers which must naturally be present in the canefields and therefore can have no significant effect. This is true only in part. When the canes are at least three quarters fully grown, and are sufficiently badly infested with borers to produce large and continuous broods of moths, host eggs are plentiful and the parasite is normally plentiful. It is usual therefore to cease adding parasites artificially at this period, though in some instances when cane growth has still permitted the distribution of parasites and large numbers of mass reared parasites were still available, it has been proved that it is possible to raise a high normal parasitism still higher by such liberations, and so to reduce the number of effective larvae which survive.

Normally, however, this is not attempted, and production and distribution of parasites is concentrated on the period when host population level is rising far more rapidly than the *Trichogramma* level, and when cane growth is at a stage when the maximum damage can be inflicted by borers and when above all, conditions are apparently favourable for a survival and effective entrance into canes of far more than 10% of the *Diatraea* larvae which hatch.

The fifth objection, namely, that an increase in the average rate of parasitism of *Diatraea* eggs is not productive of more than a very slight decrease in total damage inflicted is more difficult to counter. The answer can only come from the field results, and as cane takes nearly 18 months from planting to reaping, results are slow in accumulating, and, as will be shown later, need careful examination. For this reason, and also because *Diatraea* is present all the year round, and causes material damage over at least 12 months of the growing period, it has not yet been possible to arrange experiments to correlate intensity of infestation (or reduction in damage) with actual yield in adequately and closely checked experiments. This has, however, been done by Neiswander and Herr (4) in the case of maize infested by corn borer, and these workers have shown that within the variety there is a direct correlation between borer population and reduction in yield. There is no reason to assume that the case of moth borer in sugar cane is in any way different; in fact the presence of the borers in canes would have a more direct effect on the yield, and the correlation between population and yield would be even higher. Hence, as it can be proved on paper that increased parasitism of eggs does reduce borer population, in spite of the intervening 90% larval mortality, it is reasonable to expect that there will be a fairly high correlation in reduction in damage.

The methods adopted to ascertain both increase in parasitism over wide areas and long periods, together with the method of sampling the crop and analysing the damage due to borer over the whole island have already been published (6) and (7).

The writer fully realises however, that increased tonnage of cane crop reaped may not represent increase due entirely to reduction of moth borer population. Other factors operate to affect the tonnage of the crop namely (a) climatic fluctuations, (b) manurial and cultural improvements (c) control of other insect pests of cane, (d) introduction of new and heavier yielding varieties of cane, and possibly also improved harvesting of the crop. Improvements in extraction and manufacture of sugar will affect the sugar and syrup yields only, not the crop tonnage which alone is being considered here.

Obviously all four factors can increase tonnage yields; (a) can obviously only be approximately estimated, and four or five years at least of the control measure must be carried out before the effect of such climatic fluctuations can be eliminated. Past records of yields, rainfall, and temperatures will naturally assist in correlating yields and climatic fluctuations. Factors (b) and (d) are more definite and are taken into account. As it happens, depression and drought have not improved or increased manurial and cultural operations; whilst new varieties of cane are only now beginning to affect the yield; in fact there is some evidence of new varieties of heavier yielding cane being more attractive to borers and so much more susceptible to attack and damage that they

may do as much to raise the borer population and increase the average damage to the crop as any control measure could do to reduce it.

The third factor, control of other pests of cane has a decided effect in Barbados, for the control now in progress over *Diaprepes abbreviatus* and *Phytalus smithi* (6) has undoubtedly raised the tonnage of the crop in general.

On the other hand, the spread of gumming disease over the whole island may possibly reduce tonnage.

The writer is not therefore laying claim indiscriminately to any increase in tonnage; but it can be seen that too many variable factors are involved to enable an accurate correlation to be made between reduction in pest population level, decrease in damage, and increase in tonnage reaped.

It remains to add that, as previously mentioned, the planting community of Barbados have donated funds to double the output of parasites and have guaranteed to maintain such output for at least two years. This action would not have found such splendid support and co-operation had not the planters and factory managers been convinced by three years observation of field and factory evidence, that moth borer was being controlled.

To cope with the increased output of parasites, estimated at over 80 million for 1932 the following plan has been adopted.

The acreage under plant cane and ratoon cane for each estate or holding on the entire island was first carefully compiled and tabulated. From this it was possible to determine the amount of cane suitable for liberation of parasites each month, and also the amount of such cane on each estate.

From past experience, it is possible to estimate the number of parasites which each moth unit is likely to produce per month; it was thus possible to work out the number of parasites available per acre, and the proportionate acreage of each estate which could be treated each week.

As a result, minor distributions were possible in February, and in March organised distributions were arranged for one acre out of every four of plant cane throughout the island to receive parasites once at the rate of about 550 parasites per acre. In April one acre out of every two over the whole island receives parasites at the same rate per acre.

In May one acre in every four of plant cane receives parasites *each week;* i.e. during the month *every* acre of plant cane over the whole island has parasites liberated in it.

The extent and regularity of this plan of distribution is based on 75% or more of the planters fetching parasites regularly every week—an average based on past results; allowance is also made for applications from peasant proprietors etc. Should the demand fall below expectation, then any surplus can readily be absorbed by treating an extra acreage on estates that do fetch and distribute parasites regularly, *or* by increasing the number of eggs per slip, and so increasing the number of parasites per acre.

It is considered by the writer, however, that the number of parasites mentioned, namely 550 minimum per acre, is sufficient for the stage of cane

growth up to June at least. The frequency, regularity, and extent of the distributions will ensure that a large proportion of *Diatraea* eggs deposited will be parasitised either directly by mass reared parasites or by field parasitism which will have been established at numerous foci at earlier dates than would naturally happen.

From July onwards, ratoon canes will be sufficiently grown to need consideration, and it is at present planned to include them as well as plant canes, treating one acre in every four *every week* over the whole cane area of the island, i.e. 36,000 acres of growing cane per week at the rate of about 450 parasites for every fourth acre.

It is possible, however, that in view of the fact that ratoon canes are not usually so badly infested as plant canes, and that if the infestation of plant canes is kept down from the beginning, that ratoons will be still less infested, that therefore planters will prefer to concentrate on the plant canes alone, and either treat about one acre in two every week, or else increase the number of parasites per acre liberated in the fields chosen for treatment. The latter can be accomplished either by putting out more slips per acre, or by increasing the number of parasitised eggs per slip. The latter method would most probably be adopted, in order to save labour in the field and labour and expense in the laboratory. For these reasons, the number of slips allocated per acre has been reduced from 15 to 12.

Thus from July onwards, either one acre in every four plant and ratoon over the entire island will be treated every week at the rate of 450 parasites per acre, or plant cane only will be treated at the rate of two or three in every four acres throughout the island, or a smaller acreage of plant cane will be treated at the rate of over 2,000 parasites per acre as in the past. The treatment selected will most probably be left to the planters, who are by now becoming well acquainted with the principles underlying the distribution they make.

By the end of September, cane growth will probably be too dense (unless lack of rain has retarded growth) to permit of universal distribution of parasites, the demand will fall off, and at the same time the moth units will be failing, and nearing the time when they have to be closed down and cleaned out in rapid succession. By then, however, the average rate of parasitism will be high throughout the island, and such parasites as are available for distribution throughout October and possibly November could only be expected to affect the situation if concentrated in a few chosen areas.

This briefly is the plan now being carried into effect in Barbados, and although it has never been seriously expected that reduction in borer population due to killing more *Diatraea* eggs through increased parasitism by *Trichogramma* would produce a spectacular reduction in damage or the relegation of *D. saccharalis* to a rarity among entomological specimens, yet so long as *Trichogramma* can be mass reared economically, distributed effectively, and timed to achieve maximum effective parasitism, there is sufficient evidence in Barbados to prove that it is securing control, but none whatever to prove that it should be condemned or discarded for any other control measures, not one of which has yet been proved effective. Should, however, any introduced larval parasite become established and show conclusive evidence of

effecting an adequate reduction in borer infestation, mass production of *Trichogramma* would most probably cease, but at the present time, *Trichogramma* would appear to be working with reasonable efficiency and to be the only available method of control.

References.

1. Morrill, A. W.—A Discussion of Smith and Flanders *Trichogramma* Fad Query. Jl. Econ. Ent. Vol. 24, No. 6., p. 1264.

2. Muir, F.—The Critical Point of Parasitism and the Law of Malthus. Bull. Ent. Res. Vol. XXII, Pt. 2, p. 249.

3. Myers, J. G.—Preliminary Report on an Investigation into the Biological Control of West Indian Pests. Empire Marketing Board Report, No. 42.

4. Neiswander, C. R. and Herr, E. A.—Correlation of Corn Borer Population with Degree of Damage. Jl. Econ. Ent. Vol. 23, No. 6, p. 938.

5. Smith, H. S. and Flanders, S. E.—Is *Trichogramma* becoming a Fad? Jl. Econ. Ent., Vol. 24, No. 3, p. 666.

6. Tucker, R. W. E.—An Account of *Diatraea saccharalis* and of the Technique of Breeding *Trichogramma minutum* and of the Results of Two Years' Field Liberations of the Parasite in Barbados and Control of Root Borer—Report of the Dept. Sci. and Agric. in Barbados, 1930-31, p. 80.

7. Tucker, R. W. E., —Sugar Cane Borers,—Trop. Agriculture, Vol. VI., No. 8.

8. „ „ „ —The Control of *Diatraea saccharalis* in Barbados by Mass Liberations of *Trichogramma minutum*—Trop. Agriculture, Vol. VII, No. 11.

THE INVERSION OF SUCROSE IN SYRUP MANUFACTURE.

By

C. A. COPPIN, B.A.Sc., (TORONTO).

In the manufacture of syrups from cane juice, the inversion is usually brought about by the addition of acetic acid in the form of sour juice or vinegar. On account of its low dissociation, relatively large quantities of acid are required for the inversion; further, due to its volatility a great portion of the acetic acid is removed during evaporation.

In common practice the acid is added just after clarification of the juice. When evaporation takes place under reduced pressure as much as 60 per cent of the acid added is lost and takes no part in the inversion during the final evaporation in the open pan.

The addition of acid in the early stages of evaporation of the juice is therefore done at a disadvantage, and it is possible that its effect may be increased if addition is made at some other stage.

Now the rate of inversion of sucrose is primarily dependent on

(1) the hydrogen ion concentration (or pH) of the solution

(2) the temperature

(3) the concentration.

The optimum reaction for inversion of cane juices as recommended by Saint (1) is about pH 4.5. Lower pH's than this would require large quantities of acid, and whilst this would accelerate the rate of inversion, it might possibly confer a permanently acid, or some other objectional quality on the final syrup; pH's of higher value would require considerable time for adequate inversion.

The rate of inversion is directly proportional to the temperature—thus the rate at 100°C. is about five thousand times the rate at normal room temperature (28°C). Temperatures above 100°C. will therefore lead to further increased rates; there is however a limiting temperature since concentrated solutions of sucrose will caramelise and darken if heated much above 120°C for any considerable time.

Deer (2) also points out that other conditions being the same, the rate of inversion is proportional to the concentration—thus a 20 per cent cane sugar solution will invert twice as rapidly as a 10 per cent.

From the above considerations it is apparent that better inversions will take place at higher concentrations and at higher temperatures. Experiments along these lines indicated that the addition of acid or vinegar to cane juice should be best made when the concentration of the juice is around 25°Bé. At this concentration the temperature of the boiling juice is around 105°C., and the rate of inversion is 75 per cent greater than at 100°C. It must however be clearly noted that the pH of the juice is the greatest factor influencing the rate of inversion, thus a neutral juice or syrup suffers but little change of inversion on heating around 100°C.

If however the loss of acetic acid, and consequent rise in pH during evaporation can be minimised or eliminated, the rate of inversion could be considerably increased.

For this purpose, experiments on refluxing, or returning the condensed acid products back to the syrup were carried out. These experiments showed an increased rate of inversion; the saving in time was however not very great. and it is doubted whether the principle of refluxing could be economically employed on a large scale.

The other method adopted for maintaining a constant pH during inversion was the heating of the juices and syrups in an autoclave under pressure. The following table shows the percentage of sucrose inverted in clarified juices at different pH's when heated under pressures of 7, 15 and 25 lbs. gauge, corresponding respectively to 110, 120, and 130°C.

Temp.	Time heated.	% Sucrose Inverted pH 5.7	% Sucrose Inverted pH 5.0	% Sucrose Inverted pH 4.5
110°C.	½ hr.	0.97	1.95	2.96
	1 „	1.46	5.85	11.82
	1½ „	2.43	11.23	23.15
	2 „	5.34	16.59	28.08
120°C.	½ hr.	1.46	2.44	17.73
	1 „	4.37	14.63	31.53
	1½ „	12.62	17.56	40.89
	2 „	19.42	28.29	..
130°C.	½ hr.	2.43	13.66	..
	1 „	15.05	38.04	..
	1½ „	24.27	72.68	..
	2 „	(burnt).	..	..

The results of the above experiments indicated that

(I) Heating the juice at 130°C. for more than one hour gave dark solutions with burnt flavour; even for a shorter time the juice still acquired a slightly burnt flavour.

(II) With the pH of the juice at 4.5—heating for 1½ hours at 120°C. gave adequate inversion without burnt flavour and the resulting syrup was of satisfactory quality Bé 40.5; Pol. 32.5.

(III) Heating the same juice at 110°C. did not give sufficient inversion even after heating for 2 hours.

The clarified juice used in the above experiments was obtained by first liming the juice for clarification, removing the mud, and obtaining the necessary pH by addition of acetic acid.

It was thought desirable first to reduce the pH of the unclarified juice—thereby requiring considerably less acid—heat under pressure, and clarify subsequently. Great difficulty was, however, experienced in affecting a satisfactory clarification after the inversion, the precipitates showing a tendency to remain in suspension, or to settle at bottom rather than at the top as in normal clarification. It was easily possible however to remove them by filtration and the resulting syrup was of quite a satisfactory nature.

A further reduction of the time required for inversion was obtained by carrying out the inversions on the partially concentrated juices under pressure. Some of the above juices were concentrated in an open vessel to a syrup of 25°Bé. The pH of this syrup was then reduced by means of 5 per cent. vinegar. Due principally to the buffer action of such syrups, a greater quantity of acetic acid is required to produce the desired pH than is required for normal juice. The table shows the results of heating at 120°C. for one hour.

Original Syrup.	Syrup heated 120°C. for one hour.	Final Syrup.
pH 4.5 Sucrose 41.5 Glucose 2.7	pH 4.5 Sucrose 24.5 Glucose 16.7	Bé 41.0 Pol. 28.6 (satisfactory).
pH 5.0 Sucrose 43.6 Glucose 2.7	pH 5.0 Sucrose 38.3 Glucose 9.1	Bé 40.5 Pol. 54.2 (will crystallise).

From the above it is apparent that heating a 25° Bé syrup of pH 4.5 at 120°C. for one hour results in such inversion that the resulting final syrup will not crystallise on standing—indeed heating at 115°C. for one hour will produce

a final syrup of good marketable quality. Considerable clarification takes place during the pressure heating, and a quantity of matter is precipitated out. This settles out fairly rapidly, leaving a very much clearer and brighter syrup for final evaporation.

A process of syrup manufacture which gave an excellent syrup may be carried out thus:

The raw juice is limed to about pH 6.0 heated and clarified in the usual manner. It is then evaporated (triple effect or open tayche) until its density reaches around 25°Bé. The pH is then reduced by adding vinegar or acetic acid and the syrup heated under pressure as follows:—

pH 4.5	at 10 lbs.	gauge (115°C.)	for 1	hour
5.0	„	„	„	1½ hours
5.5	„	„	„	2 „

The heating under pressure may be done in any closed vessel provided with suitable heating coil, and capable of standing a pressure of 25-30 lbs. per square inch gauge.

After inversion the resulting syrup is allowed to settle and the clear syrup drawn off from the top. Evaporation is then continued in the Aspinall or other open pan until the desired gravity is attained. During this open evaporation the bulk of the acetic acid will be removed. The resulting syrup should give Bé 41.0, Polarisation 30-35, be quite clear and bright, and not crystallise spontaneously on standing.

References.

1. Saint, S. J.—Report Dept. Sci. & Agri. 1929-30, p. 73.

2. Noel Deer—Cane Sugar, 2nd Edition, p. 260-263.

Some Aspects of the Flora of Barbados.

BY

F. HARDY, B.A., F.G.S.

PREFACE.

The following account of the plant life of Barbados as considered in the aspect of its relationship to the conditions of growth that the various habitats within the Island present, is the outcome of six years discontinuous study of the flora of Barbados, which my duties as Lecturer in Natural and Agricultural Sciences caused me to make. It was with a view to putting on record the results of my investigations that the writing of this book was undertaken,—for in teaching Botany to boys of Harrison College, a great need was felt of a handbook of the local flora which would present the facts in such a way that interest in important biological principles would be awakened. It is to be hoped that my attempt to provide such a handbook will serve first of all as a guide to students of Botany at Harrison College or at any other school in Barbados where the study of plants forms part of the curriculum. It is even to be hoped that this book will furnish teachers in the Island with a means whereby they may be induced to encourage interest in plant life amongst their pupils, for there is a lamentable lack of knowledge of the common plants of Barbados, which becomes very apparent when beginners in serious botanical study are questioned. In the second place there are in Barbados many grown-up people who have a taste for natural history, and who feel the need of some book of reference to enable them to learn about the living objects which they see growing out of doors. This book, being specially written on the plants of Barbados, might supply the need, and might encourage a more serious study of the problems which arise out of casual observations. Finally, it might be of some use to visitors who are desirous of picking up a few facts about the plant life of the Island.

The subject matter is divided into three parts. The first of these deals with the general nature and mode of action of the factors which have been instrumental in the populating of Barbados by plants and in the distributing of those plants over the various regions within the land area. This first part is more or less academic—but nevertheless it brings in a certain number of important facts connected with the climate, topography and past history of Barbados which may be of interest to the general reader. In beginning a serious study of the botanical problems presented by the local flora, it would be wise to gain some knowledge of the structure and of the role of the various parts of a typical green plant. To this end the systematic study of the elements of plant morphology and physiology should be attempted. A book such as the up-to-date text–book named in the Bibliography at the end of this volume (No. 2 "Botany for Senior Students" by D. Thoday, 1915) provides all the requirements of the student, and, supplemented by a perusal of other general works on Botany and Agricultural Science (see Bibliography), forms an excellent ground-work for a further detailed study.

Part II deals exclusively with the vegetation of Barbados. Here an attempt is made to illustrate the relation between the plants of the Island and the environment in which they are found. The vegetation of certain districts in Barbados is described in some detail, and here the names of the more typical plants occupying those districts are given with a simple description of many of the species mentioned. It is with the naming of the plants of Barbados that considerable difficulty has been experienced. Had it not been for the existence of the excellently-preserved and carefully named dried plant specimens belonging to the Barbados Department of Agriculture, and for the great assistance so freely rendered me by Mr. J. S. Dash, B.S.A. (Assistant Superintendent of the Department), it would have been quite impossible for me to have acquired in the

time at my disposal that familiarity with the flora of the Island which was essential to a correct compilation of plant lists made during my surveys. I wish here, therefore to record my appreciation of the courtesy of Mr. J. R. Bovell, I.S.O. (Superintendent of the Barbados Department of Agriculture) in so kindly placing his herbarium at my disposal, and also to record my gratitude to Mr. Bovell and to Mr. Dash for their willing assistance. The material of the herbarium was collected in the years 1905—1906 (chiefly by Mr. Dash himself) and duplicates were sent to the New York Botanical Gardens, where Dr. N. L. Britton, the Director, determined the names of the plants, and forwarded his lists to Barbados. The plant-names have since been frequently revised and the herbarium added to. Recently (1917) Mr. Dash has built up a card index into which the accepted name of each plant according to "Index Kewensis" has been entered. But the greatest difficulty of all has been experienced in connexion with the vernacular or common names of the plants. There are so many different names for certain of the plants of Barbados (especially of wild plants), and the same common name is so often used for more than one botanically distinct plant, that the assignation of easily-remembered titles to the majority of the Barbados plants has proved to be a task yielding very unsatisfactory results. In most cases of doubt one or other of the vernacular names given in the plant list in Schomburgk's "History of Barbados" (1848) has been adopted. It will be noticed that after the name of each plant the botanical family of the species is indicated. Plants are classified in the main according to the structure of their flowers. An account of this method of classification will be found in the invaluable "Dictionary of Flowering Plants and Ferns" by J. C. Willis (Bibliography No. 3). By a use of this book the characteristics of the various families of plants alluded to in the following pages may be learned. It is to be noticed that the system of classification employed in Willis' book and also in these notes, is that due to Engler (1903). This system is in many ways more satisfactory and more up-to-date than that of Bentham and Hooker (1862—1893). The plant descriptions in this volume have, as far as possible, been kept free of abstruse botanical terms. Any expressions not in every day use that have been employed, may be found in an ordinary English dictionary. Further information of a more technical kind may be obtained from Grisebach's "Flora of the British West Indies" (1864), (Bibliography No. 20) by hunting up in the index the name of the plant about which more information is required, and then referring to its description in the letter press. I have obtained much assistance and inspiration from the beautifully written "Flora phanerogamique des Antilles francaises," by R. P. Duss (1896). (Bibliography No. 21). This book forms part of the journal of the Colonial Institute of Marseilles and is difficult to obtain in British Colonies. Had it not been for the great kindness of Sir Francis Watts (Commissioner of the Imperial Department of Agriculture for the West Indies) who willingly lent me a copy of the Flora (along with other useful books of reference in the library of the Imperial Department) I should have been quite unaware of the existence of what is perhaps the best and most recent descriptive work on West Indian plants.

Part III of this volume deals briefly with the agents which have been responsible for the introduction of plants into Barbados.

The completion of my notes has been hurried somewhat by my having decided to collect the facts I have learnt during my residence in the Island, at a

time not sufficiently previous to my date of departure. The result is that there are many passages in the book which require revision. It is to be hoped, however, that what has been compiled will, in some measure, serve the purpose for which it was written.

Before concluding I should like to express my appreciation of the kindness of Professor J. P. d'Albuquerque, Island Professor of Chemistry, in making it possible for these notes to be prepared in type for the press, and for his continued interest in my work. I also owe my thanks to Mr. B. M. L. Craig, of the Government Laboratory for making certain chemical analyses and to my former pupil, Mr. E. G. Stroud, for preparing the Index of this book. Finally, I desire to record my deep gratitude to my esteemed friend Mr. W. Nowell. (Mycologist of the Imperial Department of Agriculture and late Assistant Superintendent of the Barbados Department of Agriculture) for his constant help and valuable criticism. It is to Mr. Nowell that I owe much in the way of inspiration and of guidance in my botanical studies, and his kindness in offering to read through the proofs of this book is greatly appreciated by me.

F. HARDY,

Stafford House,
Bridgetown,
July, 1917.

CHAPTER I.

INTRODUCTION.

There are few subjects more thoroughly misunderstood by the average person than the Science of Botany. This fact becomes to a certain extent excusable when the reasons for it are exposed. Most people have some sort of an interest in the plants that grow around them—the interest being sometimes from the point of view of their beauty, sometimes of their use, and sometimes—though much more rarely—the interest is in the possible means whereby plants came to be evolved from simpler forms, and in what relation plants stand to other living things in organic nature.

Perhaps the chief reason why Botany is misunderstood by the layman is that he has received the impression (either by reading old books or by listening to the expositions of people who have only a very superficial knowledge of Botany) that a study of it aims at teaching long, unwieldy and strange-sounding names for otherwise harmless and innocent plants, and at enforcing on the beginner a new language of technical terms which is at once formidable and unattractive. It is true that every plant so far discovered, possesses a botanical name which, by reason of its frequently having been founded on Latin or Greek words, is difficult to pronounce and more difficult to remember. It is also true that the botanist occasionally makes use of certain terms in order more definitely to describe a plant, but at the same time, it must be borne in mind that names are necessary symbols, and that a simple technical term might save line after line of verbiage—an important consideration when complex plant structures are being described. In the earlier days, the student of Botany was chiefly concerned with plants considered as inanimate objects, consisting of many different and variable parts, each requiring careful tabulation and description. In those days also, while the Science was still in its infancy, much attention was paid to the recognition or discovery of new forms. The reputation of a botanist was then measured by the number of new species he had determined. It was even customary to use a sort of dog Latin in botanical writing of that period, and it is small wonder that the idea became prevalent, and was passed down from one generation to another, that Botany was a subject for a few grey-bearded specialists only—men whose normal interest in life had been so far suppressed that they approximated in "greenness" almost to the plants with which they were concerned. Here again, the idea became prevalent in the minds of the uninitiated that, since the specialists seemed to spend most of their time collecting and pressing plants—the important aim in every botanical excursion was to obtain as many "specimens" as possible. Now many of these ideas are still held by unenlightened people, and even persons of undoubted intelligence and education exhibit the most profound ignorance of the real aims of the present-day botanist; even though by their conversation and behaviour, these people exhibit a certain amount of sympathy which, with a little botanical study may easily develop into real interest in the subject.

Botany nowadays has quite a new aspect. It no longer consists in the preparation and arrangement of collected plant specimens, or in the committing to memory of scientific names of plants. It no longer deals exclusively with botanical descriptions, or with the determination of new species—although this part of Botany can never be neglected on account of the import-

ance of correct delineation of plant forms with a view of tracing descent. On the contrary, modern Botany is for the most part a fascinating, common-sense pursuit, which adds much interest to one's walks abroad and which enables one to gain real insight into the workings of Nature. Of course, it is to be understood that there are many specialists whose work lies in one or other branch of Botany—in fact the whole subject is so broad and has so many meeting places with such subjects as Chemistry, Physics, and Agriculture that one may spend a whole life time in trying to learn all that is known about a single sub-division of Botany. Such a life's work, however, is the lot of few individuals,—but much that is of interest and value may be picked up in spare time by a person of average intellect and energy, provided that sufficient inspiration and guidance is given in the first place to his early attempts to grasp the new ideas.

To put it briefly, Modern Botany aims at the elucidation of the problem of how the numberless plant forms we see around us came to be such as they are and where they are. It will be seen at once that this problem suggests two apparently different fields of inquiry. The first will be concerned with Evolution—that is, the gradual processes of change whereby one organism gives rise to others, and these in turn to further forms all of which differ in some respect from the ancestral type. The second part of the problem will deal especially with the ways in which plants become disseminated from the places where they were evolved, to other regions where they will come into competition with other already established plants and where they will be placed under conditions of life which may or may not be suited to them.

The Evolutionary aspect of the subject is perhaps the more difficult to grapple with and to understand. It involves a detailed investigation into the forms and structure of many different kinds of plant life,—from the very simple to the most complex;—an investigation which at once leads to endless lines of research, each necessitating the utmost care, ability and patience and often entailing the use of special instruments and of special technical methods of procedure. It also implicates experiments in plant-breeding which in themselves present numerous and often almost insurmountable difficulties. It can only be appreciated when some knowledge has been gained of the reasons why processes of change do go on in living organisms, and of the ways in which such alterations in form are passed on from parent to offspring. Many readable books on this Evolutionary aspect of Botany are, however, unobtainable nowadays. The pioneer of them is, of course, Darwin's "Origin of Species"—a book which did more to awaken interest and to initiate wide research in Evolutionary Biology than any other exposition has ever done. A list of easily procured and attractive books on Evolution is given in the bibliography at the end of this volume. The issue in recent years of several excellent, popular editions of scientific books makes it possible for every educated person to know something of the underlying principles and the modern trend of thought in this branch of Science, and to make himself acquainted with the main results of investigations of specialists.

The second aspect of Botany on the other hand is one which can be studied and in part first hand without the application of any very special methods, and by any lover of nature who is willing to look more closely into things around him than is his wont to do. It is this second aspect of Modern Botany that it is intended to touch upon in the following chapters,—the Flora of

Barbados furnishing data by means of which many interesting and important biological conclusions may be illustrated.

The plants of Barbados then are to be examined in such a way that insight will be gained into the methods whereby a particular land area may become populated with plants, and into the factors which govern the disrtibution of those plants once they have gained access to that area.

It will be advantageous to investigate the latter of these questions first. When we have learnt why certain plants have come to grow only in certain regions of Barbados, and when we have incidentally become acquainted with the composition of the flora of the Island, then we shall be in a position to discuss the origin of that flora and to understand how it came to be introduced into the Isand in the first place.

PART I.

THE FACTORS WHICH GOVERN THE DISTRIBUTION OF PLANTS IN BARBADOS.

CHAPTER II.

CLASSIFICATION OF THE FACTORS.

It is an obvious fact that the vegetation of Barbados varies from place to place. Most of the Island it is true is under cultivation, but there still exist a certain number of uncultivated regions (such as sea beaches, gullies, rocky waste places and roadsides) each of which, on examination, is found to possess its own characteristic assortment of plants. In a canefield even certain wild plants grow up with the canes and might eventually seriously affect their vigour were it not for the very particular care taken to keep them in check. These cane-field "weeds" (as will be pointed out in a later chapter) consist of distinctive plants —the identities and characters of which will be subsequently given. It will be found that they are of constant occurrence in cane-fields and one therefore soon learns to associate their names with this habitat.

In dry pastures close by cane-fields, few or none of the cane-field "weeds" are to be seen, while in gullies and on sea-beaches the assortment of plants again differs from that in either of the two regions, and is itself distinctive in each. Such facts as these serve to indicate that plants are distributed, not singly and haphazard, but in groups which more or less characterise the regions which they occupy. Thus the plants of cane-fields in any part of Barbados are of the same general type,—those of dry pastures of another type,—those of gullies of another; and so on.

Plant-groups which characterize certain definite regions where the general conditions are the same, as in the examples cited, are called by Botanists, Plant Associations.

In Barbados then, one may distinguish several Plant Associations, and it will be the object of subsequent chapters to examine into the nature of these and to try to learn from a study of them the reasons why plants come to be grouped together in such a constant and definite manner.

Turning our attention now to the factors which have influenced and are still influencing the vegetation of Barbados, and which have brought about the aggregation of its plants into plant associations, we realise at once that these factors are numerous and varied, and are of different degrees of importance accordingly as they affect its general nature or the nature of its minor details. It is common knowledge, for instance, that climate determines what the general nature of the plants populating a certain region will be, for we have Arctic plants, Tropical plants and Temperate plants—each of which group constitutes a definte "Zone of vegeta[illegible] within each zone of vegetation many smaller plant communities exist. [illegible]re is decided by factors such as surface -configuration, soil characteristics porosity of the underlying rocks, &c.—factors which play an

important part in connexion with the vital question of water supply. Lastly, many other factors—most of them of great complexity and of marked inter-relationship, affect the distribution of plants within the areas whose limits are defined by the more direct agencies. Of these factors, man's influence on the vegetation stands out as being particularly effective and interesting, especially in connexion with the problem with which we are immediately concerned.

From the foregoing remarks it becomes evident that an investigation into the reasons why the plant population of any land area comes to be what it is, and to exhibit marked aggregation into plant associations, is one of no little difficulty. It involves the use of considerable judgment and experience in assigning to the several factors at work their proper values.

The study of the plant associations of different areas in relation to the various factors of growth in operation in those areas is termed "Plant Oecology." (Greek oikos—a house).

Oecology as an organized study is a recent development of Botany, and was only taken up by British Botanists in the last fourteen or fifteen years. It owes its origin to Professor Warming—of the University of Copenhagen—whose book "Oecology of Plants," published in 1895 (with an English edition in 1909) is still the standard exposition of the subject.

Detailed study of any one Plant Association along oecological lines will soon indicate that within the Plant Association many smaller groups of plants may be distinguished. In a rocky district, for instance, some plants may be found growing on the bare rock itself—their roots penetrating into the pores and crevices of the rock,—whereas others are confined entirely to the pockets of soil which occur between the stones or which break up their surfaces.

The smaller plant-groups within a plant association are called "Plant Societies."

Another example of a Plant Society is the collection of plants that grows in the moister hollows or depressions in a Dry Pasture Association, and another, the group of plants that chacterises the tops of hummocks or ridges in the same association.

Before proceeding to a description of the different factors which decide the distribution of plants, mention must be made of the way in which plants growing in a given association influence each other. Take for instance the case of Forest Association. Such an association of plants includes tall trees, smaller trees and shrubs, and also many undergrowth herbs. The taller trees and shrubs shade the herbs and thus make it possible for them to live by preventing their exposure to too strong light. The presence of the trees thus decides to a certain extent the kinds of lowly plants that can populate the soil which forms the floor of the forest. In this example, the trees are said to be the *dominant species* and the undergrowth plants, the *subsidiary species*. Thus, if the dominant species of a Forest Association are tall and not overcrowded, small plants requiring shade might grow beneath them, whereas such plants would have no chance of surviving in an association in which the dominant species were low-growing. In a typical, well-established plant association there is, therefore, a balance between the several species constituting the association—since the requirements of

each kind of plant are different and the "struggle for existence" between the species is not very severe.

Turning our attention now to the nature of the factors that may influence the distribution of plants, we find that it is possible to classify the factors into four major groups. Each of these groups may be further sub-divided in a way which will be best illustrated by a tabular representation of the scheme of classification to be adopted in this book.

(I) *Climatic Factors* which act over large areas and which decide the general nature of the vegetation in such regions as Arctic regions, Temperate regions and Tropical regions. They depend on geographical situation, latitude, altitude and upon the earth's motion.

They include
1. Temperature
2. Rainfall.
3. Amount of sunshine.
4. Direction and force of the prevailing winds.

II. *Topographical Factors* which are decided by the configuration of the land and which act within the areas whose vegetation is decided broadly by the climatic factors mentioned above.

They include :—
1. Effect of altitude, slope, &c. which indirectly influence vegetation because of their effect on rainfall.

2. Effect of land masses or depressions in sheltering vegetation from winds.

3. Effect of surface features, porosity or rocks, &c. on the movement of water which has fallen on to the land as rain.

4. Effect of slope of land which influences the depth and drainage of the surface soil.

III. *Soil Factors.*

These include :—
1. *Physical properties* of the soil, which decide its moistness, its aeration, its drainage, &c.

2. *Chemical constituents* of the soil which decide the nature of the nutrient salts which it supplies to plants growing in it.

IV. *Biological Factors.*

These include :—

1. The influence of animals and man.

2. The influence of the plants on each other.

The above factors include the most important factors in operation in all parts of the world. They are instrumental in deciding the ultimate nature of the vegetation in any locality on its surface. In particular, each has played its part in bringing about the final arrangement of the plants found growing in Barbados, and many of them are still in operation there, so that their methods of working may be studied at the present day.

It is proposed to consider in turn each factor in connexion with the question of the distribution of plants in Barbados, and at the same time to attempt to decide which factors have made the greatest impression on the present-day vegetation of the Island.

CHAPTER III.

CLIMATIC FACTORS.

1. *Temperature* is of importance in deciding the general nature of the plant life of any country, because many of the processes that go on in the plants are directly influenced by it. Some plants can stand high, some low temperatures—whereas others live successfully only in surroundings where the temperature range is small. Thus Arctic plants are specially suited to life under low temperature conditions, and could not possibly exist in temperate or tropical countries.

In Barbados, and in the Tropics generally, then, only certain kinds of plants can live. Other plants such as many of those which are characteristic of temperate or arctic regions (for example, conifers and other common forest trees of northern latitudes) cannot exist there—although certain plants (for example, a number of weeds of cultivation and a few common garden plants) can thrive quite as successfully under tropical heat conditions as under those of temperate countries.

Records of the air-temperature of Barbados indicate that neither the diurnal nor the annual temperatures show any great extremes. The average annual maximum temperature is about 84°F. and the average annual minimum about 75.5°F. The temperature seldom rises above 88°F., and only occasionally falls below 67°F.

It may be concluded from these data that the soil in which the plants of Barbados grow is not subjected to seasonal changes as regards heat and cold as is the soil of temperate or northern countries. Hence the process of water absorption carried on by the roots of those plants is never suspended, but proceeds uniformly, provided always that there is a sufficient supply of water to be absorbed. In regions where summer and winter temperatures succeed one another the absorption process—influenced as it is by temperature changes,—falls off during the cold weather, and is initiated again in spring when the temperature rises. This temperature change in temperate countries, results, therefore, in a marked seasonal alternation of vegetative activity, most plants dying off or dropping their leaves in autumn and winter and springing to life and putting out fresh foliage in the spring and summer. In Barbados then, seasonal changes in plants as a result of temperature effect, are not marked. It is true that many plants do show variations in their vegetative processes, but these variations are due to the fact that the water supply is not constant—a result brought about by the increase and decrease of the rainfall during the "rainy" and "dry" seasons respectively. This point will be dealt with later when the rainfall factor is discussed.

2. *Rainfall* is of very great importance as a factor influencing vegetation in any region, since water is such an essential need in the life of every plant. Water is undoubtedly the chief agent in determining plant distribution in every sense of the term. It will be shown later that plants differ greatly in their water requirements. Some are so constructed that they require little water at their roots—since they lose so little of it by evaporation (or "transpiration") from

their leaves and stems. In other words, they are adapted for life under comparatively dry conditions. Other plants, however, cannot live unless the water supply is good, and others again can exist only when totally submerged in water. The rainfall of Barbados is, comparatively speaking, low. It has averaged about 62½ inches per annum for the last 60 years,—a marked contrast, for instance, with the rainfall of the mountainous Island of Dominica which approximates to 130 inches, and in certain districts, to as much as 300 inches per annum.

The lowness of the land in Barbados, and the absence of forests probably account in part for the smallness of the rainfall. When the Island was densely covered with trees, doubtless the annual rainfall was much higher than it is today, since the cooling effect of trees on the atmosphere into which the sea breezes bring moisture-laden air is known to bring about precipitation of that moisture in the form of rain.

The distribution of the rainfall in Barbados shows to a marked extent the influence of altitude on the quantity of rain which falls on the land. The highest parts of the Island have, in general the highest rainfall. The low lying districts in the south east of the Island suffer very considerably from drought, and it is only by careful husbandry that satisfactory results can be obtained with the crops growing there. Other low lying regions such as those that occur in the north of Barbados and along the windward coast, also frequently suffer from drought, but not to the same extent as in the other area mentioned.

The effect of rainfall in deciding the general nature of the Flora of Barbados is very great. In the first place, the fact that the Island is on the whole very much drier than neighbouring Islands such as St. Vincent, Dominica and Trinidad, is responsible for the paucity of species represented in its plant associations. Very many plants that are found growing successfully in the moister Islands of the West Indies are never found in Barbados, and it is probable that even when the Island was uninhabited by civilised man, the flora was never so rich as that of those Islands.

Secondly, although the amount of rain which falls in different parts of Barbados considerably affects cane cultivation, yet its direct influence on the wild plants of the uncultivated regions is not very pronounced. This is because the water supply of the plants of the present-day plant associations represented in Barbados, depends more on topographical and soil factors than on the superficial variations in the amount of precipitation over the different regions of the Island .

During the months of June to November the weather in Barbados is usually rainy. This period is called the "rainy season" by planters—but even during these months the showers are generally quite local—one district receiving three or four inches of rain, while another, not many miles away, receives little or none. On the average about 45 inches of rain fall in the rainy season, while the remainder (17½ inches) falls in the "dry season" extending from December to May. During the dry weather in Barbados many plants drop their leaves. This is especially noticeable in the case of several species of trees whose characteristics will be set out in full in another place, where the probable reasons for the marked periodicity in the vegetative activity of these trees will also be stated.

3. *Amount of sunshine.* This varies in different latitudes—for in northern countries the relative lengths of the day and the night differ from those in the tropics. Light is absolutely essential to the growth of green plants. On it depends their ability to build up food materials from the simple substances which they absorb from their surroundings. Many plants require bright light for success—others can live only in deep shade.

In Barbados the light conditions are exceptionally good. There are few cloudy days except in the middle of the rainy season,—and the length of the day varies but one or two hours in the different months of the year.

4. *The direction of prevailing winds* influences the distribution of the rainfall over any given land area, and thus indirectly influences the vegetation. Windward slopes of mountains and hills catch the moisture brought by the wind, while the leeward slopes remain much drier. *The force of the wind* decides to some extent what plants can survive on a given area of land because, first of all wind dries up the soil at a rate depending directly (but not entirely) on its velocity; secondly, it dries up plants unless they are specially constructed so that they lose water only slowly; and lastly, it so affects the growth of young stems, buds, &c. that it prevents many plants from becoming established on areas exposed to it, and influences also the growth forms of those plants (especially trees) that manage to survive its blast. The force of the prevailing wind is frequently also sufficient to cause an accumulation of loose surface debris, (such as sand in deserts or on the sea shore) in certain districts of a wind-swept country. Such accumulations as sand dunes influence to a marked degree the nature of the vegetation that is able to thrive on a land area covered by them.

In Barbados, the chief prevailing wind is the North East Trade Wind, which blows over the Island for the greater part of the year, with great persistency, and often with considerable violence. It exerts a marked influence on the vegetation. It is instrumental in drying up the surface soil; in drying up plants not specially constructed to resist desiccation; in bringing about peculiar growth-forms in certain trees and shrubs especially exposed to it, and in producing, in certain localities along the windward coast, small sand-dunes whose vegetation is characteristic and peculiar.

Barbados is also subjected to occasional south-easterly gales which come from the northern regions of South America. They blow spasmodically during the rainy season, but probably have little influence on the vegetation of the Island, except in so far as they affect the rainfall. Undoubtedly in former times when the Island was uninhabited by man, the effect of the prevailing winds on the vegetation of Barbados, was much less marked than it is to-day, since in the early days the outer belt of forest must have sheltered the inner regions from the deleterious action of strong and persistent air movement.

CHAPTER IV.

TOPOGRAPHICAL FACTORS.

In order to gain some idea of the influence which the topographical features of Barbados have on the distribution of plants, it is advisable to study the structure of the Island from a geological standpoint, for on its geological structure, the surface features depend. Further, the question of the origin of Barbados, that is, the history of its formation as an Island, is intimately bound up with the question of the origin of its flora. This latter aspect of the subject is to be treated specially as a separate part of this book.

GEOLOGICAL STRUCTURE OF BARBADOS

Barbados is the most easterly of the group of West Indian Islands known as the Lesser Antilles. It does not lie in the general chain of this group, but is distant some 90 miles from it—St. Vincent being its nearest neighbour. Soundings made between Barbados and other Islands in its vicinity, indicate that it is surrounded by great oceanic depressions. In many places the depths registered are between 1,000 and 1,500 fathoms—so that Barbados truly may be said to be a completely isolated land mass.

The geological structure of Barbados is comparatively simple. The Island consists of a core of sedimentary rocks, almost completely encased in a covering of coral limestone.

The core is exposed in the "Scotland District" in the north of the Island, and includes a series of much folded beds of sandstones and clays (the "Scotland Series") succeeded by white, siliceous and calcareous "earths" and clays, (the Oceanic Series")

The coral limestone covers about six-sevenths of the whole surface area of Barbados, but it is nowhere much thicker than 260 feet.

Owing to its formation as a series of coral reefs, laid down during the gradual uplift of the central core above sea level, the limestone stands out as conspicuous terraces which form an important element in the scenery of the southern and western parts of the Island.

The geological age of the "Scotland Series" is stated, on fossil evidence, to be early Tertiary—or even Cretaceous—while that of the overlying "Oceanic beds" is almost certainly late Tertiary (Pliocene or post Pliocene).

It is certain, therefore, that Barbados was in no way connected with the mainland or with other Islands of the Antillean chain during the period of its latest emergence, which conclusion furnishes the chief reason for classifying Barbados as a true Oceanic Island.

The period of its final emergence from the sea probably coincides with the Great Ice Age—an era in Geological history marked by the advance in Northern Latitudes of extensive glaciers which have left their mark on the superficial features of the whole of Northern Europe and America. The commencement of this emergence also coincides with the date of the earliest records of Man upon the earth.

TOPOGRAPHICAL FEATURES OF BARBADOS

Barbados has an extreme length of 21 miles and a width of 11 miles measured across the southerly part of the Island,— and of 5 miles across the northern part. Its total area is 166 square miles, so that Barbados is about the size of the Isle of Wight. The greatest elevation is 1,104 feet, at Mount Hillaby—a point in the rim of the much denuded core of the "Scotland District". This rim or ridge describes an almost semi-circular curve whose extremities abut on the north eastern sea coast. Its height for a length of several miles is between 1,000 and 1,100 feet above sea level. The surface features of the land within the limits of this ridge, that is, the surface features of the Scotland District, differ very markedly from those of the rest of the Island. It would be advisable, therefore, to consider the two regions separately.

1. THE SCOTLAND DISTRICT.

This district includes ridges of hills which project from the outer rim more or less radially and with a north easterly trend, towards a centre, whose position is in the vicinity of St. Andrew's Church. The natural drainage of the district is carried out by a system of small water-courses (dignified by the names of rivers on maps of Barbados) which start from the rim of the area and flow in a north easterly direction to the sea. These watercourses commence as narrow, steep valleys which contain water only in the rainy season. They quickly fall into a low level where they spread out into broader valleys—many of which are so extensive and so filled with debris washed down from the Scotland heights, that they might properly be termed alluvial flats. The main arteries of the drainage system, namely the two branches of the St. Andrew's river, are situated for the greater part of their length in extensive alluvial flats which reach a maximum development at Belle Plaine. It is quite obvious even to a cursory observer that the insignificant streamlets that now occupy the valleys of the Scotland District could not have produced the profound effects that one sees in the topographical features of the land surface in its present configuration. To have produced these effects the rainfall of Barbados must have been much heavier in former times than it is to-day, a fact that has great bearing on the question of the nature of the flora of the Island before the advent of man produced such profound changes in its composition.

The rain which falls on the land in the Scotland District at the present day at once flows down the steep hillsides—washing much of the loose debris with it—and is quickly carried by the network of small valleys into the chief drainage arteries of the district and thence to the sea. Hence the valleys and the alluvial flats are well watered whereas the steep hill and slopes remain for the most part parched and dry.

2. THE CORALLINE REGIONS OF BARBADOS.

The outer coralline portion of Barbados to the South, West and Northwest of the Scotland District stretches from the rim of the central core on the three sides roughly in two broad, step-like plateaux, each of which includes numerous minor plateaux or terraces.

(a) *Uplands.*

The first plateau immediately encircling the Scotland District has a width of about 2½ miles in the northwest, —this width narrowing down to 1½ miles in the long strip of upland that runs southward for a distance of fully 7 miles, and broadening out again as it bends round the south-western boundary of the Scotland District, to a maximum width of some 4½ miles as measured in a northwest to south-easterly direction across the Parish of St. John. The plateau finally terminates at the escarpment that faces east and overlooks the railroad in the Parishes of St. Philip and St. John. Let us deal with this first plateau in its two natural sections, the north-western and western section and the southern section. The first section lies in the Parishes of St. Lucy, St. Peter and St. James and joins the second section in the parish of St. Thomas. It falls in elevation gradually from an average height of some 780 feet at the rim of the Scotland District to an average height of some 480 feet above sea level at its north-western and western border where it terminates abruptly at a line of inland cliffs. In the north, these cliffs are not very pronounced nor very high—but rather take the form of gently rounded slopes. At Mount Gilboa, however, the escarpment takes on the form of an almost vertical wall which is continued southwards at an average height of about 80 feet above the level of the land at its base, for a distance of 8 or 9 miles. This line of cliffs forms a very conspicuous feature of the landscape in the leeward part of Barbados. Its uniformity is broken only by the numerous ravines (or "gullies") which, starting near the rim of the "Scotland District," cut through the line of cliffs and divide it up into a series of blocks. Many of these gullies contain an interesting association of plants,—one of them—Sion Hill Gully—being worthy of special notice since, because of its difficult accessibility, it has not suffered much interference by man.

Turning our attention now to the southern section of the first plateau, we notice at once that the land here takes on the general form of a broad depression. This depression is bordered on the north by the well-marked limestone escarpment which abuts on the Scotland beds between Castle Grant and Society Church—and part of which forms the well-known landmark of Hackleton's Cliff. The crest of this escarpment reaches an altitude of some 1,000 feet,—the vertical cliff wall at Hackleton's Cliff being about 70 feet high. The depression falls when traced southwards in a series of low terraces (of which that bearing Mount Tabor Church is a good example) and eventually rises again to the crest of the gently sloping and continuous escarpment which crosses at an average altitude of some 550 feet, the whole of the parish of St. George, and forms a sort of backbone of the coralline part of Barbados. The general uniformity of the upland depression described above is interrupted only by a ridge of height about 150 feet above the level of the land at its base, along

the crest of which runs the road past Gun Hill, Golden Ridge estate and Pool estate. The soil and climatic conditions in the St. George and St. John regions are so favourable to plant growth that the cane crops of this district are perhaps the best of any produced in the Island.

At several places in the southern section of the first plateau whose general features have been outlined above, many deep, narrow, dry valleys, some of them of very considerable length, cut through the plateau and the escarpment which forms its southern border. These deep valleys are known as gullies. They are especially abundant in the western part of the area—that is, in the parish of St. Thomas. It was formerly supposed that their origin was due to volcanic or earthquake agency, but this idea is entirely refuted by Harrison and Jukes-Brown in their "Geology of Barbados," p. 6. The true reason for their formation is stated (loc : cit : p. 45) to be the action of running water—a conclusion arrived at only after a full consideration of the characteristics of typical gullies, and of the relative efficacy of other possible methods by which they may have been produced. According to this explanation, the gullies must have been started when only a narrow fringing reef surrounded the central dome-shaped core of Barbados. As this core was gradually uplifted, the water courses were deepened and continued, until eventually they traversed the whole of the elevated area.

(b) *Lowlands.*

Considering next the second or lowland plateau which extends between the sea coast and the escarpment bordering the first plateau, we again find that this lowland area may conveniently be divided into two sections, —a northern and a southern.

The northern section includes the nearly flat land of the Parish of St. Lucy to the very north of Barbados, together with the strip of land, of average width 3 miles, which lies between the leeward sea coast and the line of vertical cliffs bordering the first plateau, in the Parishes of St. Peter and of St. James. In St. Lucy the flat land is terminated by high rugged sea cliffs, but in the other parishes the ground falls in a series of low terraces to a narrow sandy beach. In the southern part of this section as many as four of these terraces may be counted.

The southern section of lowland is of large area. It includes the land within the parishes of St. Michael, part of St. George, Christ Church and most of St. Philip. It is traversed by a broad valley in the trough of which runs the railroad which passes near Bulkeley, Carrington and Three Houses. There is thus in the very south of the Island between this trough and the sea coast—an elevated region which may be called the Christ Church ridge. The land falls on either side of this ridge (whose height is nowhere much more than 350 feet above sea level) in a series of low terraces—of which those near the southern sea coast are of especial prominence. The elevated land gradually decreases in height eastwards until it merges with the low flat land that borders the sea cliffs in the region of the Crane and Lord's Castle.

3. THE SEA COAST OF BARBADOS.

Having considered the features of the surface of Barbados in some detail,

it would be fitting to conclude this topographical account by describing briefly the nature of the sea coast of Barbados, — since this has considerable bearing on the different kinds of plants that are to be found associated together in the coastal regions.

The features of the sea coast of Barbados vary considerably from place to place in accordance with the kind of exposed rock and with the nature of the agents of weathering which have been responsible for the formation of the coast line of the Island.

Considering first the coralline region of Barbados, one notices that along the eastern and south-eastern coast, for a distance of about 12 miles, and again along the northern coast in the Parish of St. Lucy, for a distance of about 9 miles, the sea is bordered by steep limestone cliffs of height between 20 and 60 feet. These cliffs offer a jagged resistance line to the tearing action of the waves which beat against the land with great violence. Were it not for the presence of the encircling coral reefs which run almost the whole length of the coastal sectors under consideration, and at an average distance from the land of about 2 to 3 miles, the sea cliffs would receive the full force of the waves of the Atlantic which would cause them to be denuded at a much greater rate than at present. As it is, the cliffs in place along the south-east coast of Barbados and also of parts of the northern coast, are being broken up at a rapid rate. In historic times large pieces of the cliff face have been known to fall away into the sea and, judging by the presence of detached rocks which lie at some distance from the coast near North Point, it appears that the line of cliffs once extended much further seawards (at least in the northern part of the Island) than it does at the present time.

By reason of the great irregularity of structure and of hardness in the exposed coral rock of the sea cliffs, the features of the cliffs change rapidly from place to place. The softer coral rocks are worn away faster than the more resistant material so that the former are hollowed back into bays and inlets whilst the latter stand out as headlands. In the face of a cliff also, the resistance of the rock to the action of the sea is variable. For instance, in the north of Barbados near North Point one notices two distinct layers of coral rock exposed in the cliff-face. The upper layer is on the average about 20 feet thick and is composed of rounded lumps of coral filled and cemented together as if it were the work of a mason. The lower layer is of compact limestone and resists the action of the sea much better than does the softer upper layer. The waves have produced in places a well-marked shelf of rock whose surface is in the same plane as that which separates the two layers above-mentioned. Many caves have been produced in the softer zone above this— one of them— the "Animal Flower Cave" being of considerable extent and containing several basins in which species of Sea Anemone occur, protruding from carpets of green, crimson and salmon-coloured marine algae or sea-weeds. Here and there along the coast compressed air has produced "Blow holes" which now allow the escape of the air imprisoned in the caves and fissures by the waves as they rush forward against the cliffs. On the whole then, the sea cliffs of the coralline parts of Barbados are extremely rugged and irregular, and are constantly exposed to the waves or to salt spray that bathes them.

On the western and southern coast of Barbados the land is not exposed to the denuding action of the sea to any great extent, since the sea currents and the prevailing winds beat only against the north, north-east, east and south-east of the Island. Here there are no sea-cliffs of any importance along this coast—which extends for a distance of about 24 miles in all. For a length of 15 miles for instance, the almost straight leeward coast of Barbados meets the sea at a low-lying, sandy beach which only occasionally reaches a width of 20 yards. The remaining 9 miles of coast along the southern part of the Island, consists of low rocks with strips of sandy beaches at their bases. Only at their easterly extremity where they merge into the south-east coastal border near Christ Church Almshouse, can these rocks be said to constitute a sea-cliff.

At several places along the coast where sea-cliffs exist beaches of sand of appreciable magnitude occur. It appears that at these places the ultimate particles produced by marine denudation have been washed up by the sea at the foot of the sea-cliffs (usually in inlets where the sweep of the on-shore currents is arrested) and have there produced sandy tracts of occasionally extensive dimensions. The most noteworthy of these beaches of the coralline regions of Barbados are those at Maxwells, on the south coast; at the Crane; at Long Bay (Lord's Castle); at Foul Bay; at Long Bay (Chancery Lane) and below St. Ann's Fort at the Garrison, near Bridgetown. Many other beaches of lesser extent occur at different points round the coast of the corralline part of the Island, and it is an interesting fact that in many places, old beaches are disappearing (or have disappeared in recent times) and new beaches are being built up. Thus along the south coast, near Hastings, a beach of considerable width existed previous to about 30 years ago,—but is at the present day quite inconspicuous. The sea now washes up to the low cliff which once backed this beach at a distance of some 20 yards from high water mark. At another place about 2½ miles to the east of the above, near "Calais" the sea is depositing stones and sand on the beach—which is thereby being enlarged and extended. Within a few hundred yards of this spot, and to the east of it, a wide beach of sand has in recent years been left high and dry by the sea receding to a distance of over two hundred yards from the edge of the low cliffs that once formed its land margin. This beach is to be described in detail later. All along the southern coast of Barbados re-adjustments of the sea border are continuously going on and so quickly as the new land is exposed, just as quickly do the plants of the sea-shore invade the region and colonise it.

Considering next the Scotland district of Barbados, one notices at once a great difference between the features of the coast in this region and those of the corralline region just described. For the greater part of its length (which is in all some 10 miles) the shore is sandy and of average width about 50 yards—except where the alluvial flat known as "Belle Plaine" opens out to sea—in which district the beach is much wider. The ground rises gradually from the beach (or from the alluvial flat of Belle Plaine) and merges with the slopes which terminate the radiating chain of hills proceeding from the rim of the Scotland District. In places along the shore, the inner margin of the coral reef fringing this part of the Island protrudes through the sand exposed at low tide. The flora of the Scotland district beach differs but little from that of typical beaches in other parts of Barbados. Near Belle Plaine (at Long Point) and in places along the shore between Round Rock and Chalky Mount, a series of well-marked sand-

dunes occur, and these support a vegetation which will be described separately anon.

Let us now review what we have learnt about the general structure and topography of Barbados and apply the facts in order to try to make clear the relation between geological and topographical factors and the nature of the vegetation of the Island.

The effect of altitude is the first important point for consideration. No region in Barbados is much over 1,000 feet high, and the absence of mountainous country in the Island has in part, a great influence on the rainfall,—causing it to be so low that the growth of many kinds of plants is entirely prohibited. Also the lesser influence which the variations in level have on the distribution of rain within the borders of the Island, again affects to some small degree, the character of the vegetation. These results, however, need not again be considered here as they were dealt with under the heading of "Rainfall" in a previous section. Further, the general effect of the flatness of the greater part of the land in Barbados in not preventing the prevailing winds from blowing over it, is of no small account in limiting vegetative activity in the exposed regions. The ways in which the wind-factor acts in this connection have also been considered in a previous section. On the whole then, the effect of altitude on the vegetation of Barbados is an indirect effect, since it operates by influencing the rainfall.

The other factors connected with the structure and the surface features of Barbados, such as the effect of slope, of depressions in sheltering certain places from wind, of porosity of rocks and drainage systems in governing the flow of water which has reached the land as rain, differ so markedly in the two regions of the Island (the Scotland district and the coralline region) that their investigations might best be carried out under two headings.

1. *The Scotland District.*

In describing the surface features of this region mention was made of the effect which the natural drainage system of the district has on the water supply of the land in the valleys on the alluvial flats and on the hill slopes. Whereas there is not much chance of water accumulating in the shallow soil which covers the hill slopes, the case of the deeper valleys and the alluvial flats is quite different. The water supply here is good. In the flats the soil is deep, rich and of good tilth. It retains moisture well and is of an ideal nature for cane cultivation. On the slopes, vegetation is almost absent. The hillsides are for the most part naked, brown and barren,—except where clothed with a scanty, dry, grassy or scrubby vegetation, or coaxed into arrowroot plots by an industrious peasantry. The exposure of the hills to the direct winds from the Atlantic further aids in producing almost complete desiccation on their more windward slopes. In the valleys, however, the land is sheltered, and many of them are sufficiently moist and quiet to fit them for the growth of several kinds of fruit trees which flourish extremely well in these parts of Barbados —although not cultivated to a sufficient extent to allow of an export trade in their products.

The above account is enough to indicate that the configuration of the land in the Scotland District is primarily responsible for the distribution of plants, both wild and cultivated within the area. The steep hill-slopes, the

extensive alluvial flats and the narrow upland valleys present to plants, habitats characterised by great differences in water supply and in depth of soil, so that, here again, topographical features are seen to influence vegetation in an indirect way, and chiefly by reason of their influence on water supply.

2. *The Coralline Region of Barbados.*

The land in this region is not drained by a natural system of water courses as in the case of the Scotland District. In fact the movement of water which falls as rain in the coralline region is quite peculiar and is especially worthy of study. It has influenced to a large extent the distribution of wild plants and has played an important part in fixing the limits of certain plant associations now found in Barbados. Further, it has also influenced to a great extent the methods of cultivation practised as the outcome of experience gained by the early planters. The surface of the land of the two plateaux into which the coralline part of Barbados was, for convenience of description divided, is broken up into numerous hollows or "bottoms" which at one time must have been filled in the rainy season with water. It was the custom of the early planters to remove this stagnant water by digging sinks or "sucks" at low points in the hollows. The more compact upper layers of coral rock were cut through and the water, falling down the sinks, came on to the pervious and tunnelled lower layers of coral and could thus get away quickly. The reason why such a system of removing accumulated water rapidly instead of allowing it gradually to soak into the subsoil and into the rock below, was undoubtedly to increase the area of land which could possibly be used for cane cultivation, — an object which has been pushed so far that very little unused land capable of supporting crops exists in any part of Barbados at the present day. A simple means of conserving water by permitting it to accumulate in natural hollows in the ground has thus been sacrificed in Barbados for the sake of increasing the area of cane land. The porous nature of the coral rock, however, causes it to retain much of the water that percolates into it during wet weather. It is true that some of the water eventually finds its way into the underground watercourses which are known to ramify within the limestone in all parts of the Island, and thus to escape to the sea, but it is quite certain that the mass of coral of which the major part of Barbados is composed, absorbs, — spongelike — large quantities of water which it gives up again during the dry season. The lateral percolation or "seepage" of this subterranean water is made evident in the comparative luxuriance of the vegetation which occurs in the "undercliff" regions lying at the bases of many of the terraces which characterise the limestone districts of Barbados, and in the occasional springs which emerge from the ground in many of the undercliff localities. In fact the chief feature to lay stress on in connexion with the effect of the structure and topography of the coralline region of Barbados on the vegetation of the Island is this ability of the coral rock to absorb and retain water. The apparently remarkable character which the cane plant is locally credited with possessing, being able to live through periods of severe drought, is really in great part due, not to any special features of the structure of the plant itself, but rather to the peculiarity in the water supply with which it is provided.

Turning our attention now to the gullies which dissect the coralline region of Barbados in many districts, we notice here a very marked effect of shelter

on vegetative activity. The gullies do not serve as water courses except in very wet weather, but they do tend to accummulate water which percolates into them from the surrounding coral masses. This water is only removed at a slow rate by evaporation, since by reason of the narrowness of the gullies and the steepness of their sides, the persistent winds which do so much to dry the soils in the fields bordering the gullies, do not reach them. This fact, coupled with the comparatively small disturbing effect which the activities of man have had on the vegetation growing in gullies, is mainly responsible for the luxuriance and distinctiveness of the plant associations characterising these peculiar ravines.

Before leaving the subject of the influence of topography on vegetation in the corralline parts of Barbados, mention may be made of the effect of slope on the depth of the soil which occurs in different localities of this region. The hollows or "bottoms" are known to contain a greater thickness of soil than the ridges and knolls. Further, it is to be gathered from the account of the soils of Barbados in the pamphlet on the "Geology of Barbados" by Harrison and Jukes-Brown that much of the material of the "black" soil of the lowland districts has been brought down from higher levels by the action of rain and surface water.

(To be continued.)

MEMORANDUM.

ON

THE COTTON SITUATION IN BARBADOS.

The Pink Bollworm of cotton was discovered in Barbados in July 1923 and although by Act 29 of 1924 the destruction of old cotton plants was legally required by a fixed date in each year, and the practice of enforcing an annual close season for cotton, necessitated in previous years as a means of control for another cotton pest (the leaf blister mite). was continued, the absence of adequate staff for effecting the proper destruction of old and infected cotton plants, refuse cotton products and wild cotton, and, as a consequence, the presence of infected cotton plants in one or another part of the island throughout the year, enabled the pink bollworm to spread gradually to all districts in the island.

2. Each year from 1924 to 1927 the infection was observed to be more extensive and the damage or loss of saleable cotton greater. By the time the crop of 1926-27 reached maturity in 1927 the damage caused by the pest was so extensive that many fields of cotton were completely abandoned, and only here and there was any saleable cotton harvested.

As the result of the damage done to the crop of 1927, only a few acres of cotton were planted in 1927 for the 1927-28 crop and generally speaking cotton cultivation was abandoned.

3. In 1928, on the recommendation of the Department of Agriculture, a close season of eleven months was enforced, beginning on the 1st of July.

From the time when the pink bollworm was first observed in 1923, knowledge as to the most effective means of control was being gradually acquired, so that with the authority of the provisions of Act 31 of 1928 the Department of Agriculture was enabled to undertake measures during the long close season which resulted in the disappearance of the pest and its almost complete extermination.

In order to prevent or at least to reduce to the possible minimum the reintroduction of the pest into the Island, a new and efficient system of disinfection of imported cotton seed was established in May 1929, replacing a primitive and inefficient system.

4. During the years 1927 and 1928 the Department of Agriculture cultivated special plots of cotton for the purpose of maintaining the excellent strain of Sea-Island cotton which had been developed by its previous work.

5. An additional measure for controlling the pest within economic limits in the event of its reappearance was given effect to in the alteration of the time of planting. Hitherto the bulk of cotton seed was sown on or soon after the 1st of July in each year, but the long close season which began on 1st July 1928 was extended to the 31st of August 1929. Doubt as to the sound economics of the altered time of planting, together with a dull market, induced planters to refrain from planting more than a few trial fields, so that the crop of 1929-30

was a very small one. A very important feature of the crop, however, was the failure after careful and persistent search to discover any trace of pink bollworm.

6. Prior to the date of planting the 1930-31 crop the Department of Agriculture in Departmental Pamphlet No. 4 issued recommendations in respect of improved methods of cotton cultivation (e.g. closer spacing, windbreaks etc.) and the absence of pink bollworm in 1929-30 encouraged planters to plant a considerable area under cotton in September 1930. A very satisfactory yield was obtained from this crop, and towards the end of the crop pink bollworm was discovered in isolated areas, at a stage when it was too late to cause economic loss. Although the suitability of the altered time and new methods of planting were emphatically demonstrated by the 1930-31 crop, the almost entire absence of a market for the cotton produced has resulted in the cultivation of a smaller crop this year.

7. Unfortunately, in spite of the most rigorous clean up of the old crop of 1930-31 the pink bollworm has appeared earlier in the season this year and was first notified on January 11th, compared with February 12th in 1930.

8. It can safely be asserted that without an army of Inspectors it would be impossible to effect a more thorough clean up of old cotton bushes, okras and wild cotton trees than was carried out by the Plant Diseases Inspector and his ten Cotton Inspectors assisted very greatly by the cotton growers themselves, and if each year the pest is to make its appearance one complete month earlier or in effect to complete one more generation then some extension of the close season will have to be seriously considered.

9. It is apparent that the present close season of four months (May 1st—August 31st) is insufficient to keep down the pink bollworm and therefore it is felt that the only effective control would be by means of an additional close season of one year in four.

10. By this means it is considered that a complete economic control of the pest would be maintained and the reduction of output would go far to solving the problem of over-production or surplus stocks.

11. It is suggested therefore that control by these means should form a subject for discussion at the projected Cotton Conference.